THE UNIVERSITY OF ALBERTA

THE EFFECTS OF ISOMETRIC EXERCISE ON CERTAIN ANTHROPOMETRIC MEASUREMENTS, MUSCULAR ENDURANCE AND MUSCULAR STRENGTH OF COLLEGE WOMEN

A THESIS

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ABSTRACT

Thirty-three freshman women students, enrolled in the required physical education classes at the University of Alberta, were tested on weight; girth of the waist, hips, right thigh and right forearm; skinfold thickness of the abdomen, right rear thigh and right forearm; right quadriceps strength; right grip strength; and muscular endurance of the abdominal muscles as measured by the number of sit-ups performed in two minutes.

The subjects acted as their own controls. For the six week control period, they were excused from participation in physical education classes. They were tested again at the end of this period. For the following six weeks of the experimental period, the subjects performed two different isometric exercises daily. Six six-second contractions of the muscles of the abdominal, gluteal and thigh regions were held maximally, with the subjects in an erect standing position. Each six-second contraction was alternated by two seconds of rest. One six-second contraction of the muscles of the right hand and forearm was held maximally, with the right hand supinated and clenched and the right elbow flexed at a ninety degree angle and held against the side of the body. At the end of the six week training period, the subjects were again tested on all eleven variables.

The data from all three trials were subjected to analysis of variance. If the resulting F ratio for trial differences was found to be non-significant, the null hypothesis was not rejected. If the F ratio for trial differences was statistically significant, the null hypothesis was rejected and Duncan's New Multiple Range Test was employed to determine between which means the statistically significant mean difference lay.

Upon analysis of variance, it was found that no statistically significant mean changes had occurred in the measurements of weight; waist, hip and right forearm girth; rear thigh and forearm skinfolds; or right quadriceps strength.

Following analysis of variance and Duncan's New Multiple Range Test, it was found that there had been a mean increase in right thigh girth during the control period of 0.36 inches (statistically significant at the .01 level of confidence). Over the entire twelve weeks of the experiment, mean abdominal skinfold increased 0.99 millimetres (statistically significant at the .05 level of confidence).

During the six week period of isometric training, mean right grip strength increased 1.89 pounds, a change which was statistically significant at the .05 level of confidence. Following this period, it was found that the mean number of sit-ups performed had increased 3.3, indicating an improvement in abdominal muscular endurance that was statistically significant at the .01 level of confidence.

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CHAPTER I

STATEMENT OF THE PROBLEM

For reasons other than aesthetic, it is important to discover effective methods of strengthening the weak muscles of the abdomen, thighs and gluteal region, in women. Weak abdominal muscles allow the pelvis to sag, and lordosis and low back pain may result (1). There is also evidence that strong leg, back and abdominal muscles will be helpful during childbirth (2).

Weakness of the muscles in this area may result from sedentary habits and occupations, lack of regular exercise, or failure to regain strength following pregnancy and childbirth. It has also been observed that, as the body ages, the gluteal muscles lose the firmness of youth (3).

The standard exercise of leg-raising, often suggested for flattening and firming this area, involves mainly the hip flexor muscles, such as the iliopsoas, rather than the abdominal muscles, and, therefore, is not effective. It has been shown electromyographically that the sit-up exercise, and its variations such as the curl and V-sit, involve most effectively all abdominal muscles (4, 5).

Recently, Hettinger and Muller (6) have shown that a single daily isometric contraction at two-thirds the maximum contractile capacity of the muscle, held for six seconds, is as effective in developing the strength of a particular muscle as any other form of exercise. In 1955, Steinhaus (7) suggested that a six-second contraction of the abdominal muscles, held for a total of thirty-six seconds daily, will strengthen weak muscles of the abdominal wall, and thus aid in the development of good posture. Fox (8), however, had given evidence that faulty pelvic tilt and "sway back" were not associated with weakness in the abdominal musculature.

Day (9) has shown that daily practice of the exercise suggested by Steinhaus caused a significant reduction of waistline girth in college women, while no concomitant weight loss occurred. Although hip girth was not measured, it was felt that this measurement had decreased as well, and Day suggested that further study be undertaken in this regard.

Morehouse observed that the entire body is involved in the effort when a single voluntary brief maximal contraction is exerted against an isometric resistance, and states (10): "... palpation and electromyographic exploration of the activity of the readily accessible muscles during the effort confirm the visual observation that there is a general increase in the tone of most of the skeletal muscles in the entire body." Hellebrandt and Houtz (11) also have noted involuntary changes in body alignment accompanying muscular effort, indicating activity in muscles other than those being exercised specifically. It would appear, then, that isometric contraction of the abdominal and gluteal muscles would also cause contraction of the thigh and other muscles, and, possibly, bring about an increase in strength.

In accordance with the findings of Hettinger and Muller (6), other researchers (12, 13, 14, 15, 16, 17, 18, 19) have also achieved significant strength increases with male subjects following isometric training.

However, Mayberry (20), Wickstrom (21), Petersen (22), and Hayman and Schneider (23) have found no strength increases following isometric training. Berger (24) found that an improvement in static strength, following static training, did not result in a corresponding increase in dynamic strength.

Although it had previously been assumed (25) that isometric training would have no effect in increasing muscular endurance, Swegan (26) found that static contractions, of two-thirds maximum strength performed six seconds

daily for ten weeks, were as effective in developing muscular endurance as a weight training programme of the progressive resistance type. Dennison,Howell and Morford (27) have shown that the Arm Strength Index (I = [Chins + Dips] [Weight/10 - Height - 60]) of college men increased significantly after eight weeks of twice weekly isometric training. Meadows (28) found that ten weeks of isometric training had increased muscular endurance, as measured by the ability to perform repeated chins and dips. Liberson (29) found isometric training to be more effective than isotonic training in increasing muscular endurance, while Asa (30) found repetitive isometric training to be more effective than isotonic training, and single isometric training to be as equally effective as isotonic training. Walters, Stewart and LeClaire (31), and Howell, Kimoto and Morford (32), found no significant difference between the increases in muscular endurance brought about by isometric and isotonic training. Howell and Shaw (33) also found significant increases in muscular endurance following a training programme consisting of eight daily contractions against an immovable bar.

On the basis of these studies, there is evidence that isometric training has been effective in developing muscular strength and muscular endurance in male subjects. However, no similar evidence exists with regard to strength and muscular endurance increases in female subjects. Hettinger (34) mentions that trainability has been found to be less in women. Petersen (22) found that, while twenty-three adult male subjects made significant increases in strength following ten daily maximal isometric contractions on thirty-six occasions, the twenty-four adult female subjects showed no significant increases. Day's findings (9) indicate that isometric contractions have resulted in girth decreases in college women.

Therefore, the main purposes of this study are:

1) to determine if daily isometric contractions of the abdominal, gluteal and thigh muscles, and of the right forearm flexors, would cause any change in the girth of the waists, hips, thighs or forearms of college women.

2) to determine if daily isometric contractions of the abdominal muscles would bring about a change in the muscular endurance of these muscles.

3) to determine if daily isometric contractions of the thighs and of the forearm, would cause any change in the strength of quadriceps extension, or in grip strength, respectively.

Limitations of the Study.

1. The subjects were thirty-three freshman women at the University of Alberta, enrolled in required Physical Education 228 classes.

2. The experimental period was of six weeks duration.

3. Development of muscular strength and endurance in the muscles of the abdomen, thighs and gluteal region, resulting from isometric training, was studied in connection with isometric contractions of these muscles with the subject standing erect.

4. Isometric contraction of the muscles of the abdomen, thighs and gluteal region, was held maximally for six seconds six times daily.

5. Development of muscular strength of the forearm flexors as a result of isometric training was studied in connection with an isometric contraction of the flexors of the right forearm with the elbow flexed at right angles and the hand supinated.

6. Isometric contraction of the right forearm flexors was held maximally for six seconds daily.

Definition of Terms.

Muscular strength refers to the capacity of the muscle to exert a single explosive force against a resistance.

Muscular endurance refers to the ability of the muscle to maintain repeated contractions. It depends to a large extent on strength, but also on the viscosity of the muscle tissue as well as the efficiency of the blood supply to the muscle (35).

Isometric tension is developed when force is exerted by the muscle against an object which it cannot move. The muscle remains at virtually the same length, but technically accomplishes no work. The energy which normally would be displayed as mechanical work,is dissipated as heat (36:79).

An Isotonic contraction is performed when a muscle is able to move a load and mechanical work is accomplished (36:79). The muscle fibres, in this case, shorten and lengthen.

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CHAPTER II

REVIEW OF THE LITERATURE

Development of Strength. Recent evidence indicates that strength increases result from the effect of training on a reduction in the inhibitory effect of the extra-pyramidal system of anterior horn cell discharges which produce contractions (1).

In 1895, Roux (2) expressed the observation that an increase in muscle mass is achieved only by increasing the work effort beyond that of normal daily activity, and that this result cannot be attained merely by repeating the normal effort for longer periods of time. In 1925, Petow and Siebert (3) stated that strength development results from increased intensity of work above that previously demanded of the muscle. McCloy stated (4:69): "To improve one's strength or endurance the periodic demand on the organism must be made progressively greater, and must always be greater than the current regular demand."

This principle of 'overload' must also be observed using isometric techniques. Hettinger states (5:24): " . . . training with isometric muscle contractions has to be a progressive resistance exercise." Also, "After the tain in muscular strength the original . . . contraction would no longer represent sufficient stimulus to maintain the training effect." (5:26).

Development and Maintenance of Strength through Isometric Exercise. In 1953, Hettinger and Muller (6) published the results of their experiments on static contractions. Over an eighteen month period, nine male subjects participated in seventy-one experiments, in which training took the form of pulling and holding a pre-determined amount of tension against a spring scale, by contracting the flexors and extensors of the forearm. Some of their original findings were as follows:

1) The threshold of muscular tension necessary to get a training effect lies between 3/10 and 4/10 of the maximum strength.

2) With a training load of 2/3 maximum strength, muscle strength increases at a rate of 5 percent weekly. An increase in training load has no further effect.

3) A daily practice period in which tension is held for six seconds is as effective as longer or more frequent practice sessions.

4) If training is discontinued, strength gained at a rate of 5 percent per week is lost at approximately the same rate.

5) A muscle trained to be 50 percent stronger "... may be maintained at this level by two, probably only one, maximal contraction efforts per week." (7).

6) "When a muscle that has been trained to 50% greater strength was maintained at this level for 12 weeks by one maximal contraction per week and then given no further training nor testing, the results were astonishing. In the first 12 weeks of no special activity, strength was almost completely maintained at the high level and in the next following 28 weeks, in Professor Muller's own words, 'strength was still far from having returned to the level from which it started at the beginning of the experiment.' " (7).

Steinhaus (7) explained this phenomenon in this way: "... rapid training induces only a loosely "anchored" adjustment of the muscle to the increased demands made on it. If, however, this increased strength is maintained for a time it becomes fixated or anchored in the muscle."

More recently, Hettinger stated (5:24): "The maximum observable training effect of about 3-4 % per week was binding in these cases for the muscle biceps brachii including muscle coracobrachialis, the elbow flexors."

He also stated:

> This absolute figure changes from muscle group to muscle group, but the trend of the curve does not change in different muscle groups.
>
> It was interesting to find that the maximum training effect possible was achieved by using only 40 to 50% of the maximum strength in voluntary isometric contraction (5:25).
>
> . . . .
>
> When daily isometric contractions are reduced in their intensity to below 20% of the maximum, progressive loss in strength is observed (5:26).
>
> . . . .
>
> From these experiments, the conclusion can be drawn that it is unnecessary to require maximum contractions in order to improve muscle strength, since only 40-50% of a maximum isometric voluntary contraction produces the maximum training effect obtainable. But - and this is the important point - the intensity of the training stimulus must be increased at least every fourteen days as the maximum muscle strength itself increases during this time between the two measurements (5:26).
>
> . . . .
>
> Maintaining a maximum isometric contraction for only one to two seconds is sufficient to provide a training stimulus. When the contraction involves only 2/3 of the maximum strength, it should be maintained four to six seconds, and so on. On the other hand, muscle contractions of very short duration . . . have no effect . . . (5:28).
>
> . . . .
>
> It was found that the maximum increase in muscle strength was obtained with one training stimulus per day (5:29).
>
> . . . .
>
> Also, several maximum contractions one after the other . . . did not increase strength any faster than only one contraction (5:30).

It may be seen, from these excerpts from Hettinger's writings, that some statements differ from those originally made by Hettinger and Muller (6). Hettinger (5:31-32) concluded " . . . in practical application the maximum improvement in the strength of the muscle group being trained can be obtained by giving daily one maximum voluntary isometric contraction against a resistance for one or two seconds." He also noted that the muscles of women appear to be less responsive to training than those of men (5:44), and that it " . . . seems that the male sex-hormones are an important factor in development and in performance capacity including muscle strength . . . " (5:52).

Although the findings of Hettinger and Muller have not been exactly

duplicated, many statistically significant findings have resulted from experimentation with isometric training programmes.

Taylor (8) compared the effectiveness of four isometric training programs in developing strength in dorsal flexion of the right wrist, and outward rotation of the right thigh. For both muscle groups, Group I held a maximum pull for 12 seconds; Group II held a maximum pull for 6 seconds; Group III held a 2/3 maximum pull for 12 seconds; and Group IV held a 2/3 maximum pull for 6 seconds. No statistically significant differences were found in the four methods for producing strength, except that a 2/3 maximum contraction held for 6 seconds was significantly better at the 5 percent level of confidence, than the same method held for 12 seconds, in producing strength in right thigh outward rotation.

Lorback (9) equated two groups of thirty subjects. One group followed a standard weight training program for eight weeks, while the other group practiced static contractions, with the Cable-Tension Strength Tests developed and improved by Clarke (10, 11). It was found that the two methods were approximately equal in effectiveness, with the exception of knee flexion in which the static contraction group gained a significantly greater amount of strength than did the standard weight training group.

Mathews and Kruse (12:26) compared the results of three consecutive, 6 second maximal contractions using Clarke's Cable-Tension Strength Tests, with isotonic exercises to exhaustion on the Kelso-Hellebrandt Ergometer with a weight load equal to 3/16 maximum strength. In each of the isometric and isotonic exercise units, there were four groups of fifteen subjects, exercising two, three, four, and five times per week for four weeks. Because no common regression line existed in any group with regard to strength changes, it was concluded that strength gain is dependent upon the individual rather than upon the type of exercise he practices, or the frequency with which he exercises.

In both units, as exercise frequency increased, a greater number of subjects gained significantly in strength. Whereas 41 out of sixty subjects in the Isotonic Unit gained significantly in strength, 44 of the sixty subjects in the Isometric Unit made statistically significant gains. It will be noted that a weight load of only 3/16 maximum strength was used for the Isotonic Unit, and the authors suggested that this may not give sufficient resistance.

Wolbers and Sills (13) found that six-second maximum isometric contractions performed daily by high school boys against human resistance resulted in increases in strength, as measured by back lift, leg lift and combined hand grip, that were statistically significant at the 1 percent level of confidence.

Rarick and Larsen (14) studied three groups of post-pubescent males, equated on the basis of initial strength test scores of the wrist flexor muscles as measured by a cable tensiometer. For four weeks, the control group participated in no activity: Experimental Group I followed the Hettinger and Muller (6) procedure, holding a 2/3 maximal contraction for six seconds daily, Monday through Thursday; Experimental Group II held 80 percent maximal tension for five periods of six seconds on Monday, increasing the number of exercise bouts until reaching a maximum of eight on Thursday. It was found that both experimental groups achieved statistically significant gains in strength, at the 1 percent level of confidence, and that the differences in final scores between the two groups was not statistically significant. Four weeks after training had ceased, differences in strength retention between the two groups were not statistically significant.

Howell and Shaw (15) studied the effects of eight daily isometric contractions, held maximally for six seconds against an immovable bar, in eight different positions. It was found that strength, as measured by the back lift and leg lift, increased significantly although there was no change in grip strength. The same researchers (16), in another study in which the subjects

held one maximal isometric contraction of the right wrist flexors for six seconds daily for four weeks, found a statistically significant increase in grip strength.

Rasch and Morehouse (17) tested the effectiveness of three isometric elbow flexion curls, for 15 seconds each with 3 minutes rest, at two-thirds maximum strength. After training three days a week for six weeks, it was found that the subjects had not increased significantly in strength. However, following isometric arm elevator exercises with conditions the same as above, the isometric group showed a statistically significant increase in strength.

Following daily training sessions consisting of thirty isometric contractions at one minute intervals, Darcus and Salter (18) found a statistically significant increase in both isometric and isotonic strength. Littlefield (19) and Crakes (20) have also found statistically significant mean increases in strength following isometric training. Meadows (21) found a strength improvement, statistically significant at the 1 percent level of confidence, in vertical jump, leg lift and back lift, following isometric training three days a week for 10 weeks. Asa (22) found that repetitive isometric training (twenty daily contractions for six seconds) and single isometric training (one daily contraction of six seconds duration) both resulted in statistically significant increases in strength for all members of both groups, although the repetitive contraction group gained a significantly higher level of strength than the single contraction group. Training was carried out four days a week for twelve weeks. Liberson and Asa (23) also found repetitive isometric contractions to be more effective in the development of strength than single isometric contractions. Walters, Stewart, and LeClaire (24) studied the effects of isotonic training, isometric training with maximal resistance, and isometric training with two-thirds maximal resistance. It was found that all methods were effective in increasing strength significantly, although maximal isometric

contractions were found to be more effective than two-thirds maximal work.

Rasch and Pierson (25), studying the relationship between maximum isometric tension and breaking point strength of the forearm flexors, found that the difference between isometric contraction in pounds, and the breaking point strength in pounds, was not statistically significant at the 5 percent level of confidence.

Gersten (26) compared isometric with isotonic exercises under clinical conditions. Triceps, quadriceps, and hamstrings were tested, and it was found that both types of exercise produced marked improvement in isometric tension and in ten repetitions maximum. It was noted that the shorter time element, the lack of joint movement, and the ease of use in home programs are distinct advantages of isometric work. With regard to isotonic work, carrying the extremity through its complete range may be advantageous.

Perkins and Kaiser (27) studied the effects of short periods of isometric and isotonic exercise on older persons, aged 62 to 84 years. Group 1 performed daily isometric exercises for the ankle plantar flexors, the knee extensors and the hip extensors. Group 11 exercised similar muscle groups using the DeLorme ten repetition maximum method. After five months, Group 1 had increased 30.8 percent in strength, whereas Group 11 had improved 43.1%. The intermediate and long range effects were essentially equivalent. Berger (28) found that training statically improved static strength more than did dynamic training, and dynamic training improved dynamic strength more than static training did. Improvements in static strength did not bring about a corresponding increase in dynamic strength; the reverse was also found to be true.

In contradiction to the above-mentioned findings regarding the effectiveness of isometric training, other researchers have presented evidence that does not support the development of strength as a result of isometric

contractions. Petersen (29) studied the effects of single isometric, repetitive isometric, eccentric, and concentric contractions on the development of muscular strength. Group I trained with one maximum isometric contraction on thirty-six occasions, exercising the right elbow flexors and right knee extensors. Group II trained the same muscles with 10 daily maximal isometric contractions on thirty-six occasions. Both isometric groups trained on a Collins Dynamometer. Group III trained the right elbow flexors with 10 daily eccentric contractions on thirty-six occasions, and Group IV trained with a 15 minute ride on an ergocycle on twenty occasions. At the end of the training period, it was found that Group I, the single maximal contraction group, showed no statistically significant increases in isometric strength, as measured with a Darcus Dynamometer. Group II, the repetitive isometric group, showed a tendency toward an increase in muscular strength, although not significantly. The six male subjects increased significantly in strength measurement, but the four female subjects showed no increase. Ten daily maximum eccentric contractions, as performed by Group III, resulted in no strength increase, while Group IV, which performed concentric work on the ergocycle, showed statistically significant strength increases. Petersen (29) noted that the results failed to confirm the findings of Hettinger and Muller (6), but mentioned that their results were dependent upon experiments in which the increases in strength could be attributed to learning. Petersen (29) suggested that an increasing number of muscle contractions will lead to an increase in muscle strength. Hettinger (5:35) points out, however, that, while Petersen (29) found better trainability in the repetitive isometric group, it may have been that there were more subjects with good trainability in this group. Howell and Shaw (16), as previously mentioned, found statistically significant increases in grip strength with 19 boys who practiced one daily six-second maximal contraction of the right wrist flexors for four weeks. The increase in strength was statistically

significant "... at the .01 level of confidence for the unexercised and the exercised arm for the experimental group at the end of four weeks." (30:9).

Mayberry (31) found that maximal and submaximal isometric contractions, held for six seconds, produced no statistically significant increases in the strength of the wrist flexors or extensors. Wickstrom (32) and Hayman and Schneider (33) also observed no strength increases following isometric training. Hansen (34) studied the effects of a thirty day isometric training programme on ten young adult females. Elbow flexions were held isometrically at 60 percent of the maximum strength for five seconds; each contraction was alternated by two seconds of rest. It was concluded that the capacity to perform the specified isometric task increased significantly but that maximum isometric strength and the ability to perform dynamic contractions remained unchanged.

In 1955, Steinhaus (35) suggested that a six second contraction of the abdominal muscles held six times daily would strengthen weak muscles of the abdominal wall. Thompson (36) mentions that static contractions are effective in building strength, and that the abdominal muscles are easy to contract statically, either in the sitting or the standing position.

Day (37) studied the effects of isometric training on 72 young college women enrolled in required Physical Education golf and archery classes. Thirty-four subjects received regular instruction for six weeks, while thirty-eight subjects received regular instruction as well as practicing six second isometric contractions of the abdominal and gluteal muscles six times daily for six weeks. Waistline measurements were taken with a steel millimetre tape at the end of the six week experimental period, and three weeks after training had ceased. After three weeks of daily isometric contractions of the abdominal wall, the mean reduction in waistline girth was 0.46 inches; after six weeks, the mean reduction was 1.24 inches. Both girth decreases were statistically significant at the 1 percent level of confidence. Although hip girth was not measured,

most subjects felt that their hips had been reduced in size, and Day suggested that further study be undertaken in this regard. The control group experienced no reduction in waistline girth. There was no weight change in either group, indicating that the mean reduction in waistline girth was not a result of weight loss. Three weeks after training had ceased, mean waistline girth had increased to 25.55 inches, as compared with 25.51 inches three weeks after training had begun.

Isometric Exercise and Muscular Endurance. Although a great deal of evidence now exists with regard to the development of muscular strength through isometric training, very little has been done to investigate changes in muscular endurance resulting from an isometric programme.

Muller (38) stated that after isometric training, the time which a static contraction can be held until exhaustion remained unchanged, although maximum strength may have increased from 64 percent to 97 percent. Therefore, "... in spite of a lower tension (strength per cross section) blood supply is not remarkably better." Also, "... appropriate adaptation of ventilation and circulation to the increased muscular power must be acquired in other ways than by static muscular training." From these statements, it might be assumed that a programme of isometric training would be ineffective in improving muscular endurance.

Clarke (39), studying the energy cost of isometric exercise among twenty-four male undergraduate students, found that the size of oxygen income, the oxygen debt, and the total oxygen requirement increased linearly in proportion to the size of the weight held by the muscles. In this study, weights of fifty, thirty-five, and twenty pounds were used. When these results were compared with those for dynamic exercise, it was found that the oxygen debt was 43 percent greater for static exercise, and that the net oxygen income was 19 percent less for static exercise. Both differences were statistically

significant. It was concluded that a considerable part of the local circulation is cut off during static work.

From these observations, it would appear that static training would have no beneficial effect upon capillary circulation in the parts under contraction, and, therefore, should not improve muscular endurance. Barcroft and Miller (40) reported that, when tension increases on the Achilles tendon, the flow of blood to the Gastrocnemius muscle is decreased. Barcroft and Swan (41) have agreed with Muller (38) that blood supply and endurance are mainly a function, in static work, of uninterrupted compression of the blood vessels.

However, Asmussen, as reported by Petersen (29), found that sustained isometric work appeared to exert a greater effect on muscular endurance to static contraction than intermittent isometric work.

Baer, et al. (42) found a marked increase in the muscular endurance of the wrist flexor muscles, following heavy resistance isometric exercise, heavy resistance isotonic exercise, and low resistance complex-motion exercise.

In 1957, Swegan (43) studied the effects of static contractions and standard weight training programmes on muscular endurance. Two groups of 30 male freshmen participated in the 10 week study. Group A followed a weight training programme of the progressive resistance type, working for increased poundage, and up to ten repetitions. Group B performed static contractions at 2/3 maximum strength. The groups were equated on the basis of muscular endurance and movement speed. Muscular endurance was measured by the ability to persist in flexion at a pre-determined rate on the bicycle ergometer. It was found that both methods resulted in statistically significant increases in muscular endurance, and that there was no statistically significant differences in the final results between the two groups, although the static training method appeared to be more effective in developing endurance in knee extension.

Stoboy, Nusaggen, and Friedebold (44) found that the ability to hold

a maximum isometric effort to exhaustion increased with isometric training.

Meadows (21) found that muscular endurance, as measured by the ability to perform repeated chins and dips, was increased following ten weeks of isometric training. Liberson and Asa (23) studied three groups - one following the DeLorme isotonic method; one performing one daily six-second isometric contraction; and, one performing twenty daily isometric contractions of six seconds duration. It was found that the isometric groups experienced greater changes in muscular endurance than did the isotonic group. Single isometric, repetitive isometric and isotonic exercises were studied by Asa (22), who found a greater increase in endurance by the repetitive isometric group than by the isotonic group, and no difference between the single isometric group and the isotonic group. Walters, Stewart, and LeClaire (24) observed gains in muscular endurance following isotonic training, isometric training with maximum resistance, and isometric training with two-thirds maximum resistance.

Dennison, Howell, and Morford (45) equated two groups of ten subjects each, enrolled in required physical education classes, on the basis of their scores in the Arm Strength Index (I = [Chins + Dips] [Weight/10 - Height - 60]), as devised by Rogers and reported by Mathews (46). Group I participated in a weight training programme, using standard weights and following a standard training routine, with a minimum of five and a maximum of ten repetitions. Group II practiced the thirteen isometric exercises of the Commander Set, outlined by Steinhaus (47). Maximum contractions were held for six seconds in each of the exercise positions. Both groups met twice weekly at the same time for a period of eight weeks.

At the end of this period, Group I, the isotonic weight training group, showed statistically significant improvements in chinning (at the 1 percent level of confidence: $t = 3.6$); in dipping (at the 2 percent level of

confidence: t = 3.1); and in Arm Strength Index (at the 1 percent level of confidence: t = 4.22).

Group II, the isometric Commander Set group, showed statistically significant improvements, at the 5 percent level of confidence, in chinning (t = 2.6); in dipping (t = 2.7); and in Arm Strength Index (t = 2.75).

The differences between the two groups in the final test were not statistically significant (dipping, t = 0; chinning, t = 0.17; Arm Strength Index, t = 0.78).

Howell, Kimoto, and Morford (48) equated an experimental group and a control group on the basis of performance on a bicycle ergometer with a 14 kilogram resistance. Improvement in muscular endurance, as measured by two minutes on the bicycle ergometer, was shown by both the weight training group and the Commander Set group. Both groups improved at the 1 percent level of confidence, and no statistically significant difference was found between the two groups.

Howell and Shaw (15) found that eight daily contractions against a bar in eight different positions, held maximally for six seconds, resulted in an increase in muscular endurance, as measured by chins, dips and the Arm Strength Index.

Lawrence, Mayer, and Mathews (49) found that isometric exercises were instrumental in bringing about a statistically significant increases in the endurance of the quadriceps muscles.

Muscular endurance is measured by the ability of a subject to persist in a movement. Walters and Partridge (50, 51) have shown, electromyographically, that variations of the sit-up are most effective in producing activity in all abdominal muscles, and, therefore, this exercise will be used to study muscular endurance of the abdominal muscles, mainly the rectus abdominis.

Anthropometry. 1. Girth Measurements. Sills stated (52:44):

> There are several methods that have been suggested for taking girth measurements ... ; the one which best standardizes the technique is that which involves light contact around the periphery of the part measured with no indentation of the skin. The major objection to taking girth measurements with pressure is that of causing the subcutaneous tissue and fat to shift when the tape is applied. When (1) the proper landmarks are carefully observed, (2) the contact of the tape with the skin is carefully maintained without excessive pressure, and (3) the position of the subject is standardized, then an objective and reliable measurement will be obtained.
>
> The measurement ... of abdominal girth(s) is somewhat complicated by the excursion of the thoracic cage during normal breathing. For this reason, the excursion of the ... abdomen may be followed during quiet breathing and the mean of the largest and smallest measurements recorded.

An outline of anthropometric techniques has been prepared by the Iowa Child Welfare Research Station at the University of Iowa (53). It has been suggested that the girth of the abdomen be measured at the level of the umbilicus and at right angles to the vertebral column. The subject is directed to stand naturally with the upper extremities held slightly away from the body, and the tester stands in front of the subject and passes the tape around the abdomen. With regard to forearm girth, the same report suggests that the hand of the subject be rotated to the anatomical position and that the forearm be flexed slightly. The tape is then placed around the forearm immediately below the joint of the elbow and the horizontal plane of the greatest girth is located. For the measurement of thigh circumference, the subject is directed to stand with the feet about nine inches apart so that there is no contact between the medial surfaces of the thighs. The tape is then applied, from the rear of the subject, below the gluteal fold and around the medial bulge of the thigh at right angles to the long axis of the leg.

Concerning the measurement of hip circumference, Sills (52:43) mentioned the most lateral point of the great trochanter of the femur as being one of the landmarks of the body. Cureton (54:109) appears to use this landmark for the measurement of hips and glutei.

Sills also stated (52:44): "Girth measurements should be taken by means of an anthropometric steel tape since other tapes are subject to error as a result of stretching or shrinkage." The Iowa report on anthropometric techniques (53), also mentions that a steel millimetre tape is to be used.

Cureton (55) suggested that girth measurements be taken over tensed muscles. However, because attention in this study is focused upon girths of women in normal positions,girth measurements will be taken with the muscles in a normal state of contraction.

2. Skinfold Measurements. One of the methods for estimating the proportion of body fat is by measuring with a caliper, the thickness of folds of skin and subcutaneous tissue, which is pulled away from underlying muscles and bone. The requirements for an accurate caliper are as follows (56):

> 1. The faces of the caliper should be rectangular of size 6 by 15, mm. with well rounded edges and corners.
>
> 2. The pressure of the faces should not vary by more than 2.0 gm/mm^2 over the range of openings 2 - 40 mm.
>
> 3. For results which can be reproduced with accuracy, the pressure should lie in the range 9 - 20 gm/mm^2. The pressure of 10 gm/mm^2 is suggested as standard value.
>
> 4. The scale of the instrument should be such that readings can be taken preferably to the nearest .01 mm.
>
> A skinfold caliper which meets these requirements was developed at the Harpenden Growth Study . . . .

Sills (52:44) mentioned the Harpenden Skinfold Caliper as being one of the newer calipers which eliminated the possibility of error attributed to the spring in the Franzen-type caliper. Roby (57:275) has reported a test-retest reliability, with this instrument, of 0.97, while Clarke, Geser and Hunsdon (58) found a reliability coefficient of 0.98. Edwards et al. (59) showed a variation of only 0.5 millimetres in 19 out of 20 readings, and Yuhasz (60), comparing the Harpenden and Franzen-type calipers, found that the Harpenden Caliper gave better same-day test reliabilities in 8 out of 10

measurements. Tanner and Whitehouse observed that (56): "Duplicate measurements at the same site by the same observer agree more closely for small than for large readings, the measuring area increasing roughly in proportion to the size of the measurement." They noted that, with a jaw opening of 7 millimetres, there was a duplicate measurement difference of only 0.3 to 0.6 millimetres.

The following general procedure has been carried out by several researchers (56, 57, 60):

1. The thumb and forefinger of the left hand grasp firmly the fold of skin, pulling it away from the underlying muscle.

2. The contact surfaces of the caliper are placed one centimetre away from the fingers.

3. As greater pressure is exerted by the caliper, the pressure exerted by the thumb and forefinger is lessened slightly.

4. The scissor grip of the caliper held in the right hand, is released while the right hand continues to support the weight of the instrument.

5. When the dial needle stops moving, the reading is taken to the nearest 1/10 millimetre. "The large hand can make two complete revolutions, the first measuring from 0 to 20 mm., the second from 20 to 40 mm. The position of the small hand indicates whether one is in the 0 to 20 or 20 to 40 phase. The maximum measurement registerable is 50 mm." (50).

6. The right hand then squeezes the grip of the caliper, releasing it and removing it from the skinfold. Then the fold is released from between the fingers.

Care must be taken to avoid excessive compression of the skinfold. Brozek, Brock, Fidanza, and Keys (61) found that, if measurements were made in rapid succession, the skinfold measurement decreased. This is probably due to the displacement of fluids caused by the pressure of the caliper and the fingers.

As many as fifty-three body sites of measurement have been described (62), but for the purposes of this study, only three have been used. With regard to the measurement of abdominal skinfolds, McCloy (63:368) gives these

instructions:

> <u>Fat measurement on abdomen.</u> The measurer applies the calipers on the front of the abdomen in a line between the nipple and the umbilicus just over the border of the rib cartilage. The blades of the caliper are parallel to the line from the nipple to the umbilicus.

Yuhasz (60:2) states:

> (5) Umbilical. The skinfold is located to the left of, adjacent to and in line with the navel. The fold is lifted parallel to the long axis of the body.

This position has also been used by Cureton (54:110).

Yuhasz (60:2) measured rear thigh skinfold, as follows:

> (7) Rear Thigh. The skinfold is located midway on the back of the upper leg. The leg is held in the same position as in the front thigh measurement. The skinfold is lifted parallel to the long axis of the leg.

Regarding the front thigh measurement, Yuhasz said that the "... foot is placed on a six inch step with the knee slightly flexed and muscles relaxed." (60:2). Cureton (54:110) measured this skinfold with the foot raised so that the knee was at right angles.

Bullen and Hardy (64) have noted that women tend to accumulate fat in the hip, thigh, and abdominal areas. Yuhasz (60:1) recommends that the rear thigh skinfold measurement replaces the chest skinfold measurement with females.

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CHAPTER III

METHODS AND PROCEDURE

<u>Selection of Subjects.</u> The subjects were 33 freshman women, aged from seventeen years and two months to twenty years and two months, who were enrolled in the required first year Physical Education 228 programme at the University of Alberta in Edmonton.

Until the beginning of the study, the subjects had attended physical education classes which met twice weekly for thirty-five minutes. All classes were instructed by the experimenter. For six weeks, instruction had been given in creative dance, and for four weeks, the class had been instructed in badminton.

Although the experiment began with forty-seven subjects, the data for fourteen subjects had to be discarded because of illness, accidents, withdrawal from university, failure to perform the prescribed exercises each day, or intensive participation on university athletic teams.

<u>Duration of the Experiment.</u> The entire study was of twelve weeks duration, six weeks serving as the control period and six weeks serving as the experimental period.

In the week preceding the beginning of the control period, the subjects were given the following tests: weight; girth measurements; subcutaneous fat measurements; grip strength; strength of quadriceps extension; and muscular endurance as measured by the total number of sit-ups performed in two minutes. Four days later, the subjects were re-tested in order to establish the reliability of the measurements. The re-test scores served as initial scores for the control period.

For the next six weeks, the control period, the subjects were excused from attendance at physical education classes, but were allowed to pursue normal activities. At the end of this six week period, all tests were

repeated. The results served as final scores for the control period, and as initial scores for the experimental period.

For the following six weeks, the subjects were again excused from physical education classes, but were required to report daily, Monday through Friday, to the Physical Education Building, to perform the prescribed isometric exercises, under the supervision of the experimenter. Final tests were given at the end of this period.

Test Apparatus. The following equipment was used:

a. one weight scale.

b. one Martin Circummeter D.B.P. steel anthropometric tape.

c. one Harpenden Skinfold Caliper.

d. one cable tensiometer, of 100 pounds maximum tension, for measuring grip strength.

e. one specially-constructed arm chair, to which the cable tensiometer for measuring grip strength was affixed.

f. one cable tensiometer, of 200 pounds maximum tension, for measuring strength of quadriceps extension.

g. one table, to which the cable tensiometer for measuring quadriceps extension could be affixed, and on which the subject sat.

h. one mat, on which sit-ups were performed.

Test Methods and Procedure. All testers were senior and graduate students in the School of Physical Education at the University of Alberta in Edmonton. All were trained beforehand in the administration of the tests and each tester administered the same test throughout. One tester performed all the girth measurements; another performed all the skinfold measurements; another tested grip strength; another tested strength of quadriceps extension; another measured weight and determined the number of sit-ups.

Each subject was provided with a record sheet. The tester made the measurement and the data was then recorded. A sample record sheet may be

found in Appendix B.

A representative sample of each test, with the exception of weight, was photographed.

The tests were administered as follows:

Step I. Weight. The subject was barefooted, and dressed in shorts and a T-shirt. Her weight was recorded in pounds to the nearest quarter-pound. During each testing session, the subject's weight was recorded at the same time of day. It was necessary to keep an accurate record of the weight of each subject in order to determine if any changes in girth were related to changes in weight.

Step II. Girth Measurements. All girth measurements were taken next to the skin with a Martin Circummeter D. B. P. steel anthropometric tape, and were recorded to the nearest 1/8 inch. The tape was held in light contact with the skin, with no indentation (1:44). A device on the tape allowed uniform tension to be exerted with each measurement, and marked the actual measurement on the tape while the tape was removed from the body for more accurate reading.

a. Waist Girth (Figure I). The subject stood in a natural manner with the head erect, and the arms held slightly away from the body. The tester stood in front of the subject and passed the tape around the abdomen so that it crossed in front at the level of the umbilicus, and lay in a plane at right angles to the vertebral column. In cases of umbilical protrusion, the tape crossed at a level immediately above the umbilicus. The measurement recorded was the median value during normal respiration (2).

b. Hip Girth (Figure II). The subject stood in a normal manner, with the feet together and the arms held slightly away from the sides. The tester stood at the side of the subject and passed the tape around the most lateral portion of the greater trochanters. The plane of the tape was at right

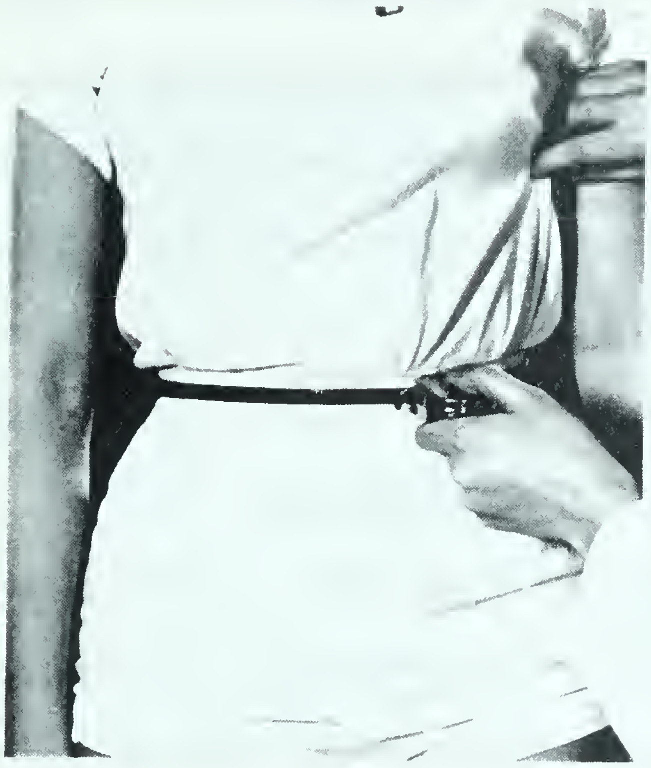

FIGURE I. Measurement of Waist Girth

FIGURE II. Measurement of Hip Girth

NOTE: ALL girth measurements were actually taken next to the skin.

FIGURE III. Measurement of Thigh Girth

FIGURE IV. Measurement of Forearm Girth

angles to the long axis of the body.

c. Thigh Girth (Figure III). The subject stood with the inner borders of her feet nine inches apart, so that the medial surfaces of the thighs were not in contact with each other. The weight was equally distributed over both feet. The tester stood at the rear of the subject, and passing the tape around the right thigh, adjusted it so that it lay at right angles to the long axis of the leg just below the gluteal fold, and through the maximum "bulge" of the medial surface (2).

d. Forearm Girth (Figure IV). The subject stood erect with the right forearm flexed at right angles to the upper arm, and with the hand supinated. The muscles of the forearm were in a relaxed state. The tester stood in front of the subject, and passed the tape around the largest circumference of the forearm at the junction of the upper and middle thirds, so that it lay in a plane at right angles to the long axis of the arm.

Step III. Skinfold Measurements. In order to establish that any change in girth was the result of isometric training rather than changes in subcutaneous fat deposits, it was necessary to keep an accurate record of skinfold measurements. For measuring skinfold thickness, the Harpenden Skinfold Caliper (Figure V) was used. The measuring procedure was as follows (3, 4, 5):

1. The thumb and forefinger of the left hand grasped firmly the fold of skin, pulling it away from the underlying bone and muscle.

2. The contact surfaces of the caliper were placed one centimetre away from the fingers.

3. As greater pressure was exerted by the caliper, the pressure exerted by the thumb and forefinger was lessened slightly.

4. The scissor grip of the caliper held in the right hand was released while the right hand continued to support the instrument.

5. When the dial needle stopped moving, the reading was taken to

FIGURE V. Harpenden Skinfold Caliper

FIGURE VI. Measurement of Abdominal Skinfold

FIGURE VII. Measurement of Rear Thigh Skinfold

FIGURE VIII. Measurement of Forearm Skinfold

the nearest 1/10 millimetre.

6. The right hand then squeezed the grip of the caliper, releasing it, and removing it from the skinfold. Then the fold was released from between the fingers.

Skinfold measurements were taken at the following sites:

1. Abdominal (Figure VI). The skinfold was located to the left of, adjacent to, and in line with, the umbilicus. The fold was lifted parallel to the long axis of the body.

2. Right Rear Thigh (Figure VII). The subject stood with her right foot elevated six inches so that her knee was slightly flexed and muscles relaxed. The skinfold was lifted parallel to the long axis of the leg, at a point midway in the back of the upper leg.

3. Right Forearm (Figure VIII). The right forearm of the subject was held slightly away from the body and the elbow was flexed at right angles. The hand was supinated. The skinfold was lifted, on the inner palmar surface of the right forearm, parallel to the long axis of the arm, at the junction of the middle and upper thirds.

Step IV. Strength of Quadriceps Extension (Figure IX). The subject sat on the end of a specially constructed table, with her knees just over the edge. The angle between her lower right leg and right thigh, as measured with a goniometer, was 115 degrees. A belt was passed around her lower leg midway between the ankle and the knee. To this was fastened a cable and to the cable, a chain, which was hooked to the base of the table, allowing the angle of knee flexion to remain at 115 degrees. A tensiometer was placed on the cable. On the command "lift", the subject attempted to straighten her right leg as forcibly as possible. She was allowed to brace her hands on the table beside her hips, but was prevented from lifting the buttocks or flexing the arms (6:92). Only one trial was given, and the reading was recorded on the dial

FIGURE IX. Measurement of Quadriceps Strength

FIGURE X. Measurement of Grip Strength

FIGURE XI. Measurement of Endurance of the Abdominal Muscles

of the tensiometer. Before the beginning of the experiment, all subjects had been given practice trials on two separate days.

Step V. Grip Strength (Figure X). The subject sat erect in a specially constructed arm chair to which a cable tensiometer had been affixed. The back of the right forearm was placed against the arm of the chair, the elbow was flexed at right angles and the hand was supinated. The subject grasped the handles of the tensiometer and squeezed them together as forcibly as possible. Only one trial was allowed.

To overcome any large initial learning effects, all subjects had been given practice trials on two days before the experiment began.

Step VI. Muscular Endurance of the Abdomen (Figure XI). The subject lay on her back on a mat, with her feet flat on the floor, her knees partially flexed, her hands clasped behind her neck and her elbows held in close to her body. She was then required to sit up to an upright position, and return to the original position. The total number of times that the upright position was assumed, in two minutes, was recorded. The feet of the subject were held by another subject. The flexion of the knees lessened involvement of the hip flexor muscles to a marked degree.

Experimental Procedure. During the final six weeks, which served as the actual experimental period, all subjects were required to report daily to the Physical Education Building, Monday through Friday, to perform the prescribed exercise under the direction of the experimenter.

The instructions were given as follows:

1. Stand normally; inhale, then exhale and hold the exhalation. Contract and tighten, as strongly as you can, the muscles of the abdomen, thighs, and hips. Hold this contraction for six seconds. Relax for two seconds. Now, inhale, exhale, and tighten again. . . .
(This exercise is performed six times for six seconds each time, daily, for six weeks).

2. Stand normally; hold the right upper arm against the right side

> and flex the elbow at a ninety degree angle, with the palm facing up. Squeeze the right fist as strongly as possible, until it is shaking. Hold this contraction for six seconds. Relax.

The holding of the exhalation while contracting in Exercise #1 prevents the use of the respiratory muscles in retracting the abdomen. The exercise was performed six times daily in order to insure that each set of muscles was held in a state of contraction for six seconds.

Holding the arm against the side in Exercise #2 insured a standardized position each time the contraction took place. The strength testing with the cable tensiometer took place in this position as well.

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CHAPTER IV

RESULTS AND DISCUSSION

Results

Thirty-three freshman women were tested on the following eleven variables: weight; girth of the waist, hips, right thigh and right forearm; skinfold thickness of the abdomen, right rear thigh and right forearm; strength of right knee extension; right grip strength; and abdominal muscular endurance as measured by the ability to perform sit-ups for two minutes. Four days later, all subjects were retested at the same time of day and by the same testers on all eleven variables.

The Pearson Product-Moment method was used to determine the test-retest reliability of all the measurements used. For weight, the correlation coefficient was found to be 0.996, while the mean reliability found for the girth measurements was 0.96 (forearm 0.98, right thigh 0.97, hips 0.95 and waist 0.93). For skinfold measurements, the mean reliability was found to be 0.91 (abdomen 0.96, forearm 0.92 and rear thigh 0.85). The reliability for the measurement of knee extension strength was 0.81, for grip strength 0.69 and for sit-ups 0.68. A summary of these findings may be seen in Table 1.

TABLE 1

TEST-RETEST RELIABILITY COEFFICIENTS

Variable	r	Variable	r
1. Weight	0.996	7. Right Rear Thigh Skinfold	0.85
2. Waist Girth	0.93	8. Right Forearm Skinfold	0.92
3. Hip Girth	0.95	9. Right Knee Extension Strength	0.81
4. Right Thigh Girth	0.97	10. Right Grip Strength	0.69
5. Right Forearm Girth	0.98	11. Abdominal Muscular Endurance (number of sit-ups)	0.68
6. Abdominal Skinfold	0.96		

The subjects in the experiment served as their own controls. The retest scores were considered to be the Trial 1 scores, the initial scores for the control period which lasted for six weeks. At the end of this period, all subjects were tested again (Trial 2) on all eleven variables. The Trial 2 scores then served as the final scores for the control period as well as for the initial scores for the experimental period. For the next six weeks, the subjects participated in a daily isometric training programme. Final tests (Trial 3) were given at the end of this period.

The null hypothesis was then stated: H: $\bar{X}_1 = \bar{X}_2 = \bar{X}_3 = \bar{X}$. This hypothesis assumes that there is no true difference between population means, and that any difference found between sample means is accidental and unimportant. All data for each of the eleven variables were then subjected to analysis of variance to determine if the null hypothesis should be accepted or rejected. If the resulting F ratio were found to be significant, the null hypothesis must be rejected and further testing must be done in order to find which mean difference is significant. Duncan's New Multiple Range Test was used to determine if the changes occurred during the control period, during the experimental period or during the entire experiment. The analysis of variance also indicates if some subjects have made significant changes during the experiment.

On Trial 1, the mean weight was 125.31 pounds (range 92.75 to 156.50 pounds). The mean waist girth was 25.14 inches (range 22.25 to 28.38 inches) and the mean hip girth was found to be 36.53 inches (range 32.31 to 39.63 inches). The mean abdominal skinfold measurement was 10.56 millimetres (range 6.3 to 25.2 millimetres) and the mean number of sit-ups performed was 26.75 (range 7 to 46 sit-ups).

The mean thigh girth was 20.97 inches (range 17.75 to 23.50 inches), while the mean rear thigh skinfold was 28.3 millimetres (range 20.1 to 38.1

millimetres) and the mean quadriceps strength was 155.91 pounds (range 90 to 210 pounds).

The mean forearm girth was 8.94 inches (range 7.63 to 10.0 inches) with a mean forearm skinfold measurement of 7.6 millimetres (4.0 to 13.0 millimetres). The mean grip strength, for the right hand, was 68.6 pounds (range 52 to 83 pounds).

Following the six week control period, Trial 2 measurements were taken. It was found that mean weight had increased 0.05 pounds, mean waist girth had decreased 0.01 inches, while mean hip girth had increased 0.175 inches, mean abdominal skinfold had increased 0.72 millimetres and the mean number of sit-ups performed decreased 1.14. None of these changes was found to be statistically significant when the data was subjected to analysis of variance.

It was found that mean thigh girth had increased 0.36 inches (Table XII). Analysis of variance and Duncan's New Multiple Range Test showed this increase to be significant at the .01 level of confidence (Table XIII). Mean rear thigh skinfold increased 0.63 millimetres following the control period and the mean quadriceps strength score had increased 11.15 pounds.

Mean forearm girth increased 0.17 inches and mean forearm skinfold increased 0.20 millimetres during the control period. The mean grip strength score had decreased 0.50 pounds.

During the next six weeks, the subjects participated in a daily isometric training programme in which they performed isometric contractions of the muscles of the abdominal, gluteal and thigh regions and of the muscles of of the right hand and forearm. Following this period, Trial 3 tests were given.

All scores from the three trials were subjected to analysis of

variance. The variance ratio or F ratio obtained for trial differences (df_1 equal to 2 and df_2 equal to 64) had to fall beyond 3.15 at the .05 level of confidence and beyond 4.98 at the .01 level of confidence, in order to justify rejection of the mull hypothesis. If the F ratio was found to be statistically significant and the null hypothesis was rejected, the differences between the means were subjected to Duncan's New Multiple Range Test, at the .05 and .01 levels of confidence, in order to determine which of the three mean changes ($\bar{X}_1 - \bar{X}_2$, $\bar{X}_2 - \bar{X}_3$ or $\bar{X}_1 - \bar{X}_3$) was the statistically significant mean change.

The F ratio for subject differences (df_1 equal to 32 and df_2 equal to 64) had to fall beyond 1.65 at the .05 level of confidence and 2.03 at the .01 level of confidence in order to be statistically significant. A statistically significant F for subject differences indicates that some subjects changed significantly more than others during the course of the experiment.

It was found that mean weight had increased 0.42 pounds following the experimental period. The F ratio obtained for trial differences was 0.4573, which was not statistically significant, although the F ratio for subject differences was statistically significant at the .01 level of confidence. This indicated that, while no overall changes had occurred, some subjects had changed consistently more than others. A summary of this data may be seen in Tables II and III.

TABLE II

CHANGES IN WEIGHT MEASUREMENTS

Group	Initial Mean	Final Mean	M diff
Control	125.31	125.36	0.05
Experimental	125.36	125.78	0.42

TABLE III

ANALYSIS OF VARIANCE FOR WEIGHT MEASUREMENTS

Source of Variation	df	Sum of Squares	Variance	F	
Between trials	2	4.429	2.2145	F_{trials}	0.4573
Among subjects	32	24,827.698	775.8655	$F_{subjects}$	160.23 **
Interaction	64	309.905	4.8422		
Total	98	25,142.032			

** Statistically significant at the .01 level of confidence.

Mean waist girth decreased 0.27 inches following the experimental period. The F ratio for trial differences was not statistically significant, indicating that the null hypothesis must not be rejected. The F ratio for subject differences was found to be statistically significant at the .01 level of confidence. The changes in waist girth may be seen in Table IV and the analysis of variance data in Table V.

TABLE IV

CHANGES IN WAIST GIRTH

Group	Initial Mean	Final Mean	M Diff.
Control	25.14	25.13	-0.01
Experimental	25.13	24.86	-0.27

TABLE V

ANALYSIS OF VARIANCE FOR WAIST GIRTH

Source of Variation	df	Sum of Squares	Variance	F	
Between trials	2	1.616	0.808	F_{trials}	2.95
Among subjects	32	289.336	0.0417	$F_{subjects}$	33.00 **
Interaction	64	17.545	0.2741		
Total	98	308.497			

** Statistically significant at the .01 level of confidence.

Following the experimental period, mean hip girth decreased 0.06 inches. The non-significant F ratio for trial differences obtained by analysis of variance indicated that none of the mean changes in hip girth was statistically significant, although a statistically significant F ratio for subject differences was found. A summary of changes in hip girth may be seen in Table VI and Table VII.

TABLE VI

CHANGES IN HIP GIRTH

Group	Initial Mean	Final Mean	M Diff.
Control	36.525	36.70	0.175
Experimental	36.70	36.64	-0.06

TABLE VII

ANALYSIS OF VARIANCE FOR HIP GIRTH

Source of Variation	df	Sum of Squares	Variance	F	
Between trials	2	.53344	0.26672	F_{trials}	1.41
Among subjects	32	288.986	0.031	$F_{subjects}$	47.7 **
Interaction	64	12.13	0.189		
Total	98	301.64944			

** Statistically significant at the .01 level of confidence.

Following the six week isometric training period, it was found that mean abdominal skinfold had increased 0.27 millimetres as may be seen in Table VIII. Following analysis of variance, an F ratio of 3.91, which was statistically significant at the .05 level of confidence, was obtained (Table IX). Upon application of Duncan's New Multiple Range Test, it was found that the mean increase which had occurred during the control period was not statistically significant, nor was the mean increase in abdominal skinfold during the experimental period. However, the mean increase that had taken place during the entire twelve weeks of the experiment was found to be statistically significant at the .05 level of confidence. The F ratio for individual differences was again statistically significant at the .01 level of confidence.

TABLE VIII

CHANGES IN ABDOMINAL SKINFOLD

Group	Initial Mean	Final Mean	Mean Diff	df	Shortest Significant Range
Control	10.56	11.28	0.72		
Experimental	11.28	11.55	0.27		
$\bar{X}_1 - \bar{X}_2$			0.99	64	0.7678 *

* Statistically significant at the .05 level of confidence.

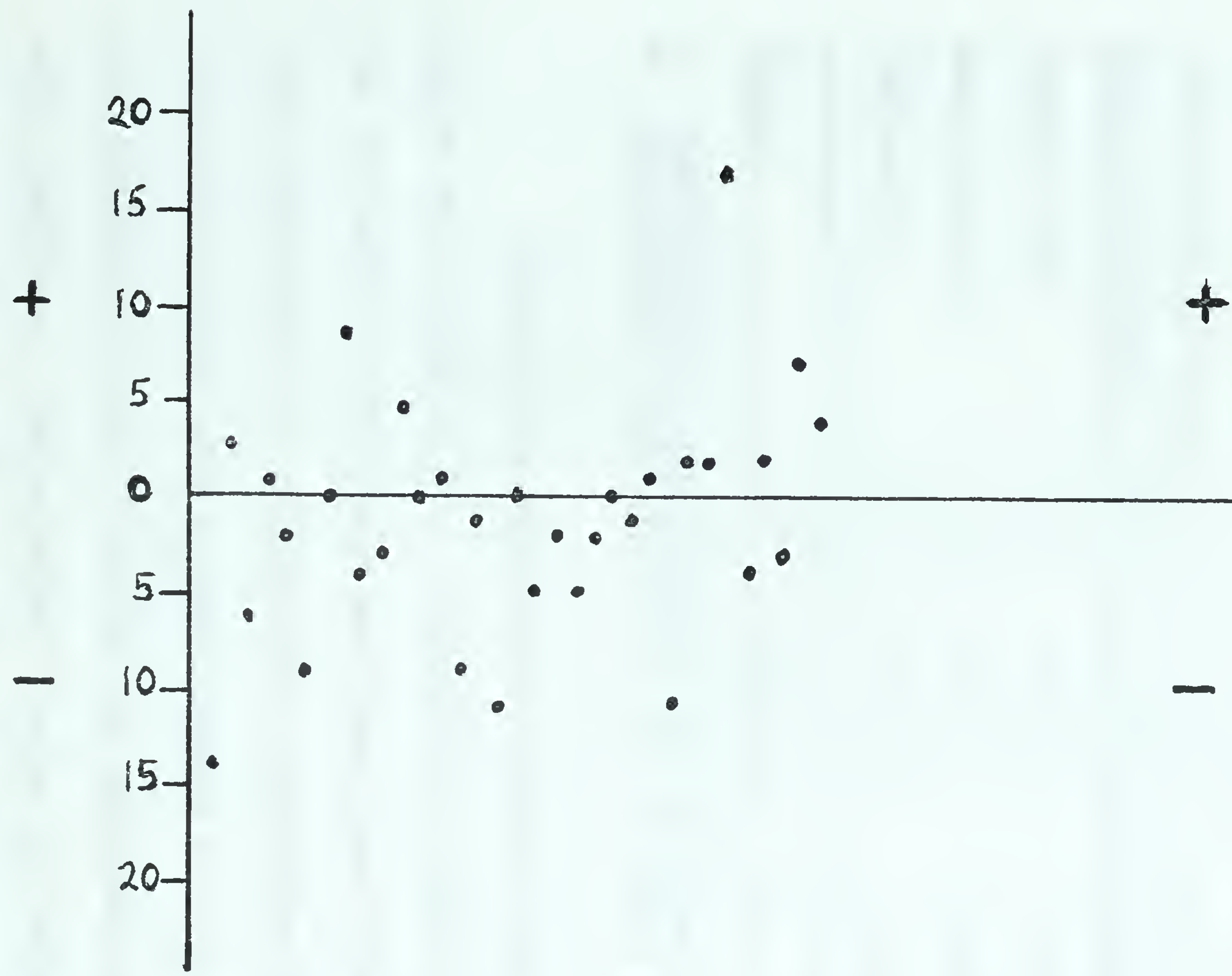
TABLE IX

ANALYSIS OF VARIANCE FOR ABDOMINAL SKINFOLD

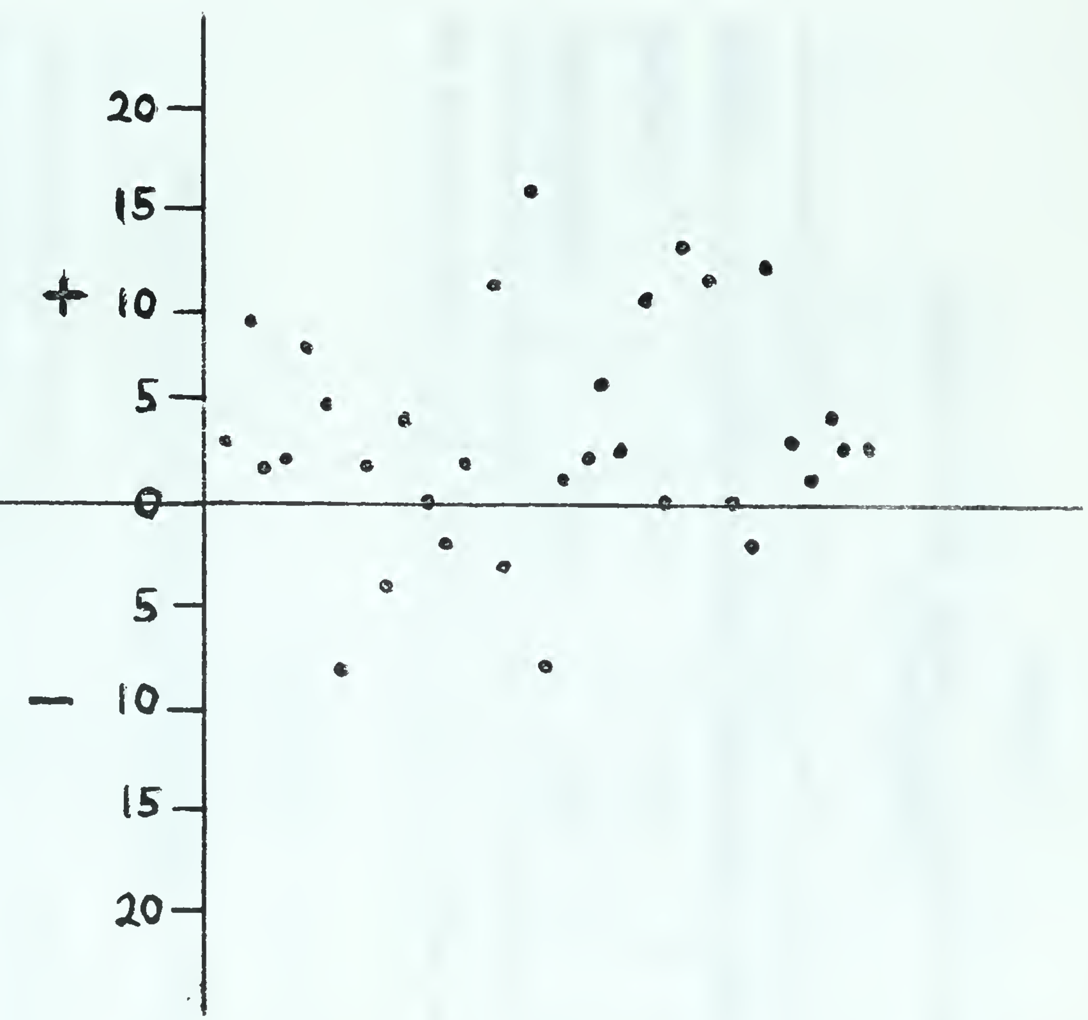
Source of Variation	df	Sum of Squares	Variance	F		
Between trial	2	17.15535	8.57765	Ftrials	3.91	*
Among subjects	32	2253.65	70.4265	Fsubjects	35.0	**
Interaction	64	140.5712	2,1964			
Total	98	2411.37655				

* Statistically significant at the .05 level of confidence.
** Statistically significant at the .01 level of confidence.

Following the experimental period, the mean number of sit-ups performed in two minutes had increased 3.3 (Table X). The F ratio obtained for trial differences (4.33) was statistically significant at the .05 level of confidence (Table XI). By use of Duncan's New Multiple Range Test, it was found that the mean increase of 3.3 sit-ups following the period of isometric training exceeded the shortest significant range at the .01 level of confidence (3.16). The F ratio for subject differences was found to be statistically significant at the .01 level of confidence. Examination of Figure XII will indicate the number of subjects who increased their ability to perform sit-ups. It was noted, following the six week control period, that seventeen of the thirty-three subjects decreased their scores, twelve subjects increased their scores and four subjects maintained the same score. Following the six week isometric training period, twenty-four subjects increased the number of sit-ups performed, six subjects decreased in their performance and three subjects remained the same. The increases ranged from one to thirteen sit-ups.



a. Changes during the Control Period
$(\bar{X}_1 - \bar{X}_2)$



b. Changes during the Experimental Period
$(\bar{X}_2 - \bar{X}_3)$

FIGURE XII. Individual Changes in the Number of Sit-ups Performed in Two Minutes

TABLE X

CHANGES IN THE NUMBER OF SIT-UPS PERFORMED IN TWO MINUTES

Group	Initial Mean	Final Mean	Mean Diff	df	Shortest Significant Range
Control	26.75	25.61	-1.14		
Experimental	25.61	28.91	3.3	64	3.16 **

** Statistically significant at the .01 level of confidence.

TABLE XI

ANALYSIS OF VARIANCE FOR THE NUMBER OF SIT-UPS PERFORMED IN TWO MINUTES

Source of Variation	df	Sum of Squares	Variance	F	
Between trial	2	185.151	92.776	F_{trials}	4.33 *
Among subjects	32	7223.55	225.736	$F_{subjects}$	2.43 **
Interaction	64	1371.518	21.4299		
Total	98	8780.182			

* Statistically significant at the .05 level of confidence.
** Statistically significant at the .01 level of confidence.

Thigh girth measurements showed a mean decrease of 0.18 inches, as may be seen in Table XII. Although an F ratio statistically significant at the .01 level of confidence was found, use of Duncan's New Multiple Range Test showed that the statistically significant change had taken place during the control period with a mean increase of 0.36 inches (Table XIII). The mean decrease of 0.18 following the experimental period was not statistically significant. The obtained F ratio for subject differences was statistically significant at the .01 level of confidence.

TABLE XII

CHANGES IN THIGH GIRTH

Group	Initial Mean	Final Mean	Mean Diff	df	Shortest Significant Range
Control	20.92	21.280	0.36	64	0.2471 **
Experimental	21.28	21.1025	-0.18		

** Statistically significant at the .01 level of confidence.

TABLE XIII

ANALYSIS OF VARIANCE FOR THIGH GIRTH

Source of Variation	df	Sum of Squares	Variance	F	
Between trials	2	2.18	1.09	F_{trials}	8.4 **
Among subjects	32	201.25	6.29	$F_{subjects}$	48.4 **
Interaction	64	8.49	0.13		
Total	98	211.92			

** Statistically significant at the .01 level of confidence.

Mean rear thigh skinfold measurement increased 0.31 millimetres, as may be seen from Table XIV. Analysis of variance produced an F ratio of 1.76 for trial differences, which was not statistically significant, although the F ratio for individual subject differences was significant (Table XV).

TABLE XIV

CHANGE IN REAR THIGH SKINFOLD

Group	Initial Mean	Final Mean	M Diff
Control	28.3	28.93	0.63
Experimental	28.93	29.35	0.42

TABLE XV

ANALYSIS OF VARIANCE FOR REAR THIGH SKINFOLD

Source of Variation	df	Sum of Squares	Variance	F	
Between trials	2	18.5697	9.2848	F_{trials}	1.76
Among subjects	32	1542.937	48.2167	$F_{subjects}$	9.14 **
Interaction	64	337.6103	5,2751		
Total	98	1899.1170			

** Statistically significant at the .01 level of confidence.

Quadriceps strength showed a mean decrease of 10.82 pounds following the experimental period (Table XVI). The F ratio of 3.02 for trial differences fell just short of statistical significance at the .05 level (Table XVIII). The F ratio for subject differences was statistically significant. Although the F ratio for trial differences was non-significant, indicating that the mean increase during the control period and the mean decrease during the experimental period were not statistically significant, examination of Figure XIII shows individual changes in quadriceps strength. Following the control period, nineteen of the thirty-three subjects increased their quadriceps strength scores, thirteen decreased their scores and one

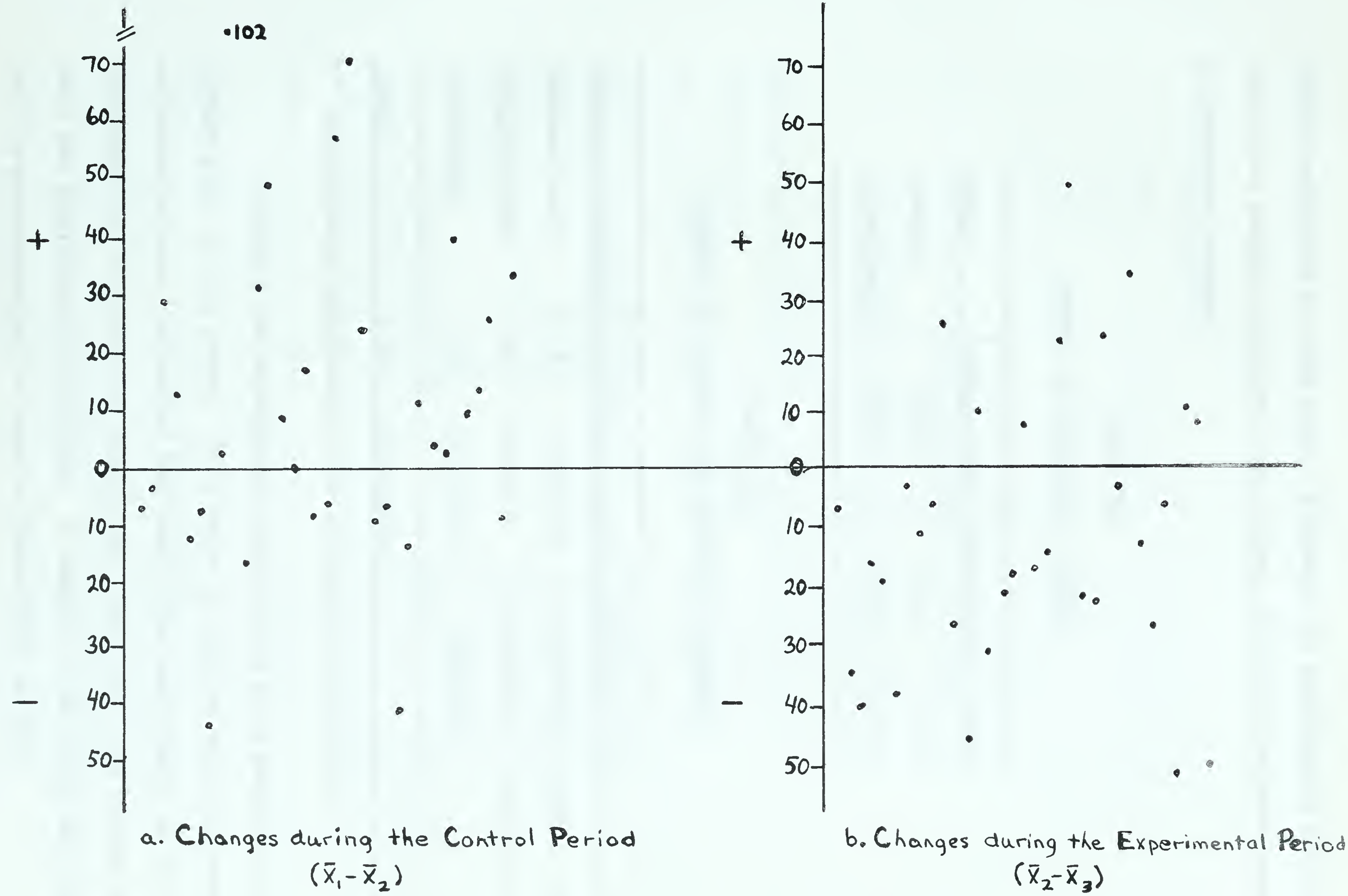


FIGURE XIII. Individual Changes in Right Quadriceps Strength in Pounds

subject maintained the same score. Following the experimental period, twenty-four subjects decreased their scores, while nine subjects increased in quadriceps strength.

TABLE XVI

CHANGES IN QUADRICEPS STRENGTH

Group	Initial Mean	Final Mean	M Diff
Control	155.91	167.06	11.15
Experimental	167.06	156.24	-10.82

TABLE XVII

ANALYSIS OF VARIANCE FOR QUADRICEPS STRENGTH

Source of Variation	df	Sum of Squares	Variance	F
Between trials	2	2,656.533	1,328.2665	F_{trials} 3.02
Among subjects	32	96,668.53	3,020.8915	$F_{subjects}$ 6.87 **
Interaction	64	28,140.137	439.6896	
Total	98	127,465.200		

** Statistically significant at the .01 level of confidence.

Following the experimental period, there was a mean decrease in forearm girth of 0.02 inches. The F ratio of 2.46 for trial differences was non-significant, indicating that none of the mean changes in this girth measurement was statistically significant. The F ratio for subject differences was statistically significant. A summary of the values and statistics for this measurement may be found in Tables XVIII and XIX.

TABLE XVIII

CHANGES IN FOREARM GIRTH

Group	Initial Mean	Final Mean	M Diff
Control	8.94	9.01	0.07
Experimental	9.01	8.99	-0.02

TABLE XIX

ANALYSIS OF VARIANCE FOR FOREARM GIRTH

Source of Variation	df	Sum of Squares	Variance	F	
Between trials	2	.0811	.04055	F_{trials}	2.46
Among subjects	32	33.669	1.0521	$F_{subjects}$	63.76 **
Interaction	64	1.061	.0165		
Total	98	34.8111			

** Statistically significant at the .01 level of confidence.

Mean forearm skinfold showed a decrease of 0.3 millimetres following the experimental period (Table XX). The F ratio of 1.35 for trial differences was not statistically significant, while the F ratio for individual differences was statistically significant (Table XXI).

TABLE XX

CHANGES IN FOREARM SKINFOLD

Group	Initial Mean	Final Mean	M Diff
Control	7.6	7.8	0.2
Experimental	7.8	7.5	-0.3

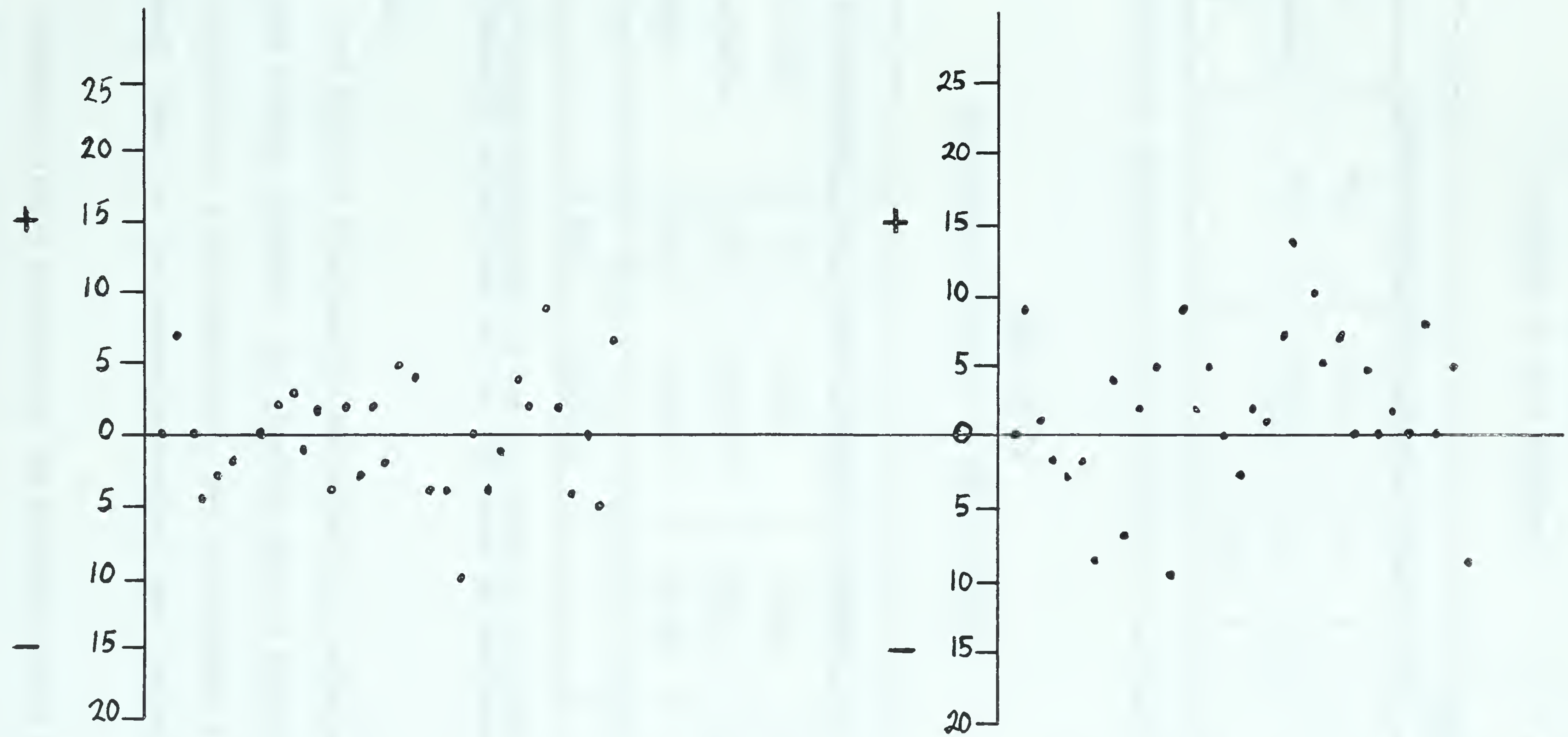
TABLE XXI

ANALYSIS OF VARIANCE FOR FOREARM SKINFOLD

Source of Variation	df	Sum of Squares	Variance	F	
Between trials	2	1.557	0.7785	F_{trials}	1.35
Among subjects	32	365.53	11.4228	$F_{subjects}$	19.78 **
Interaction	64	36.9694	0.5776		
Total	98	404.0564			

** Statistically significant at the .01 level of confidence.

Grip strength showed a mean increase of 1.89 pounds following the six week isometric training period (Table XXII). The F ratio of 3.6 for trial differences was statistically significant at the .05 level of confidence. By use of Duncan's New Multiple Range Test, it was found that the mean increase of 1.89 pounds following the experimental period was statistically significant at the .05 level of confidence, just exceeding the shortest significant range value of 1.886 (Table XXIII). The overall mean increase from Trial 1 to Trial 3 was also statistically significant at the .05 level of confidence, exceeding the shortest significant range of 1.99 for 3 means. The F ratio obtained for subject differences was statistically significant at the .01 level of confidence. From examination of Figure XIV, it may be seen that, following the six week control period, fourteen of the thirty-three subjects increased their grip strength scores, while fourteen subjects showed a decrease in this measurement and five subjects maintained the same score. Following the six week isometric training period, nineteen subjects increased their scores, while eight subjects decreased and six subjects kept the same score. The increases ranged from one to fourteen pounds.



a. Changes during the Control Period ($\bar{X}_1 - \bar{X}_2$)

b. Changes during the Experimental Period ($\bar{X}_2 - \bar{X}_3$)

FIGURE XIV. Individual Changes in Right Grip Strength in Pounds

TABLE XXII

CHANGES IN GRIP STRENGTH

Group	Initial Mean	Final Mean	M Diff	df	Shortest Significant Ranges
Control	68.6	69.1	0.5		
Experimental	69.1	70.99	1.89	64	1.886 **
$\bar{X}_1 - \bar{X}_2$			2.39		1.99 **

** Statistically significant at the .01 level of confidence.

TABLE XXIII

ANALYSIS OF VARIANCE OF GRIP STRENGTH

Source of Variation	df	Sum of Squares	Variance	F	
Between trials	2	105.9	52.95	F_{trials}	3.6 *
Among subjects	32	8,103.78	253.95	$F_{subjects}$	17.23 **
Interaction	64	940.77	14.70		
Total	98	9,150.45			

* Statistically significant at the .05 level of confidence.
** Statistically significant at the .01 level of confidence.

Discussion

The level of relationship indicated by a correlation coefficient depends upon several factors: the absolute size of the coefficient; the purpose for which the r was calculated; how the obtained r compares with the r's generally found for the variables studied; and, the variability of the scores.

Garrett (1:176) states that the following rules will act as a guide in the interpretation of r.

r from .00 to ± .20	very low or negligible
r from ±.20 to ± .40	low; present but slight
r from ±.40 to ± .70	substantial or marked
r from ±.70 to ± 1.00	high to very high

Mathews (2:24) states that an r of 0.90 to 0.99 indicates excellent agreement between the variables, whereas an r of 0.80 to 0.89 is considered fair. Reliability coefficients of 0.70 to 0.79 are considered poor to fair and those from 0.60 to 0.69 are considered poor. Larson and Yocom (3:163) state: "The standard of acceptable reliability is 0.90 or above for individual use, and 0.75 or above for group application."

All reliability coefficients calculated in the present study were applied to groups and were compared to values obtained by other researchers.

For the weight and girth variables, the test-retest reliability coefficients, as determined by the Pearson Product-Moment method, were found to be high. For weight, the reliability was 0.996, while for girth measurements, the mean reliability was 0.96.

For the skinfold measurements, the mean test-retest reliability was 0.91 which is lower than those of 0.98, 0.97 and 0.94 - 0.99 reported by other researchers (4, 5, 6). Although reliability coefficients of 0.96 for measurements of abdominal skinfold and 0.92 for forearm skinfold were found, the reliability of the rear thigh skinfold measurement was 0.85. This relatively low coefficient of reliability, as compared to those values reported by other researchers, may be due to the difficulty in isolating the skin and fat, at this particular site, from the underlying muscle. This problem in isolating the skinfold may have been accentuated, in this case, by the fact that the subjects were relatively inactive young women whose rear thigh muscles were not firm, and therefore it may have been difficult for the tester to differentiate between skin and fat, and muscle on some subjects.

The test-retest reliability coefficient for the measurement of quadriceps strength was found to be 0.81, which is a lower value than the r

of 0.94 reported by Clarke (7:136) for this test. Beasley (8) had stated that a reliability of less than 0.8 would indicate that the test was unreliable and that 0.95 was satisfactory. The relatively low reliability found in the present study may have been due to changes within the measuring instrument itself or faulty measuring technique by the testor, or may have been the result of learning (although practice trials had been given on two previous occasions), or may have resulted from the desire on the part of some subjects to avoid possible muscle soreness following the exertion, while other subjects desired to increase their test scores. It is interesting to note that, in the work done by Beasley (8), none of his 1364 subjects of both sexes and all ages were young women in the age range from seventeen to twenty years. It has been observed that many girls of this age, who have experienced muscle stiffness or soreness following exertion, will not put forth a maximum effort on further trials.

The reliability coefficient for the grip strength measurement was very low at 0.69. Clarke (7), had previously reported a reliability for palmar flexion, on the cable-tension strength tests, of 0.93, and Bowers (9) had found a reliability of 0.94 using a cable tensiometer in a hand grip apparatus identical to that used in this study. The relatively low reliability found in the present study may have been the result of the same reasons as mentioned for the reliability of quadriceps strength.

Muscular endurance was measured by the number of sit-ups that could be performed by the subject in two minutes. The reliability coefficient was found to be 0.68. Larson and Yocom (3) had previously reported that sit-ups as a test of muscular endurance show only moderate reliability (0.8 to 0.9). The motivation of the individual greatly affects the number of sit-ups that can be performed and girls especially may wish to avoid any possible muscular discomfort following exertion of this type. The relatively low r may also be

attributed to muscular stiffness on the retest, which took place only four days after the first test.

During the control period, the mean weight of the subjects increased 0.05 pounds, and following the six week experimental period, there was a mean weight increase of 0.42 pounds. Neither of these increases was found to be statistically significant ($F_{trials} = 0.46$).

Mean waist girth decreased 0.01 inches during the control period and 0.27 inches during the experimental period. The F ratio of 2.95 for trial differences was not statistically significant, indicating that no statistically significant decreases in waist girth had taken place. It must be noted here that Day (10) had reported a mean decrease of 1.24 inches in the waistlines of college women following six weeks of isometric training, using the same isometric exercise for abdominal, gluteal and thigh muscles as used in this experiment. Day (10) found that the mean waist girth decrease was statistically significant at the .01 level of confidence and suggested that hip girth, although not measured, had decreased as well. In the present study, the mean decrease in hip girth was 0.06 inches, which was not statistically significant, nor were the mean decreases of 0.18 inches in thigh girth or 0.02 inches in forearm girth. It is possible that the subjects used by Day may have been more trainable. Mathews and Kruse (11) have pointed out that strength changes appear to be dependent upon individual differences.

Although no statistically significant changes in girth took place following six weeks of isometric contractions, all thirty-three subjects made the subjective observation that the abdominal, gluteal and thigh muscles were firmer and that the abdominal wall was "flatter". This "flattening" may have been the result of learning to hold the abdominal muscles in a partial state of contraction or may have been due to increased strength in the abdominal muscles.

Following analysis of variance and Duncan's New Multiple Range Test upon the data for thigh girth, it was found that the mean increase in thigh girth of 0.37 inches, following the control period, was statistically significant at the .01 level of confidence. Such an increase may be attributed to the fact that the six week control period included the three week Christmas vacation, as well as the mid-term study and examination period of two weeks. At this time, it may be assumed that the subjects would be less active than usual. With this inactivity, it might be expected that weight and fat deposits would increase. It has been noted that, with an increase in weight, women tend to accumulate fat in the hip, thigh and abdominal regions (12). However, examination of the data revealed that, while thigh girth increased significantly during the control period, there were no corresponding increases in weight or in thigh skinfold measurement. These results may have been partially due to the measuring techniques that were employed. Thigh girth was measured just below the gluteal fold around the medial bulge, as suggested in the outline for anthropometric techniques published by the Iowa Child Welfare Research Station (13), while rear thigh skinfold was taken, with the foot raised and the knee flexed, at a point on the back of the thigh midway between the knee and the gluteal fold, as suggested by Cureton (14) and Yuhasz (15). It is felt that more meaningful results may have been obtained if the thigh skinfold measurement had been taken at the same site where thigh girth was measured. With the foot raised and the knee flexed, it is a relatively simple matter to pick up a skinfold, isolated from the underlying tissue, on the antero-medial aspect of the thigh adjacent and anterior to the medial bulge and in a plane parallel to the long axis of the thigh.

If such a procedure were followed, it would be possible to determine if thigh girth changes were associated with changes in thigh skinfold. Weight did not increase significantly during this period, but, nevertheless,

it is felt that the statistically significant increase in thigh girth was the result of the accumulation of fat in this area because of the relative inactivity of the subjects at that time.

Although non-significant F ratios for trial differences were obtained for the forearm and rear thigh skinfold measurements, the F ratio for the abdominal skinfold data was statistically significant at the .05 level of confidence. Further treatment of the data by use of Duncan's New Multiple Range Test indicated that the statistically significant change (at the .05 level of confidence) had been a mean increase of 0.99 millimetres from Trial 1 to Trial 3, during the entire twelve weeks of the experiment. As Bullen and Hardy (12) have noted that this is an area in which fat tends to accumulate, it is assumed that the increased mean skinfold measurement at this site is the result of increased fat deposits in this area, although weight and waist girth showed no statistically significant changes. The relative inactivity of the subjects during the twelve week period may be the reason for the increase in fat deposits.

Other researchers (11, 16, 17, 18, 19, 20, 21, 22, 23) have found statistically significant increases in muscular strength following isometric training. The results of the present study showed no statistically significant change in the strength of quadriceps muscles ($F = 3.02$), but showed a mean increase of 1.89 pounds in grip strength, statistically significant at the .05 level of confidence ($F = 3.6$).

The lack of statistically significant change with regard to quadriceps strength is in accordance with the findings in other studies (24, 25, 26, 27). However, during the six week control period, there was a mean increase in quadriceps strength of 11.15 pounds, and during the six week experimental period, there was a mean decrease of 10.82 pounds. Examination of Figure XIII reveals that, during the control period, 19 of the thirty-three

subjects increased their scores, while 13 decreased and one maintained the same score. During the experimental period, 24 subjects decreased their scores, while only 9 showed any increase.

The apparent, although not statistically significant mean increase during the control period and mean decrease during the experimental period may be partially explained by the fact that all the subjects, in their required physical education classes, had been given six weeks of twice-weekly instruction in creative dance and four weeks of twice-weekly instruction in badminton, prior to the beginning of the control period. It is possible that the strenuous activity in the dance classes may have caused the quadriceps muscles to develop an unusually high degree of strength and that participation in badminton maintained this level. The slight increase in mean quadriceps strength during the control period may have been due to the practice effect of using the measuring apparatus and the subsequent decrease during the experimental period may have taken place because the prescribed isometric exercise did not present a training stimulus of sufficient intensity to maintain the strength level acquired in the dance classes. This explanation is borne out when the force/body weight ratio of these girls at the beginning of the control period is compared to the mean force/body weight ratio found by Beasley (8) when he examined 1364 normal individuals. The ratio found by Beasley was 0.979, while for these thirty-three girls, the ratio was 1.23, indicating a relatively high level of quadriceps strength.

Another explanation for these results, which are in discrepancy with the increases found by other researchers, may be that, while the strength of knee extension was measured using Clarke's cable-tension strength test for quadriceps where the subject is seated and attempts to straighten the knee against a resistance, the isometric training took place with a contraction in the erect standing position. Morehouse (28) has noted that strength training

tends to be specific. It is recommended that subjects be trained by attempting to extend the knee against a resistance, as in the test for quadriceps strength. Hansen (29) found that isometric training increased the capacity of young female subjects to perform the specified isometric task, but did not increase their maximum isometric strength.

Mean grip strength increased 0.5 pounds during the control period and 1.89 pounds during the experimental period. An F ratio of 3.6 for trial differences indicated that a statistically significant change had occurred and use of Duncan's New Multiple Range Test showed that an increase in grip strength, statistically significant at the .05 level of confidence, had taken place following six weeks of isometric training. The training contraction took place with the hand in the same position as when tested with the cable tensiometer. The overall mean grip strength for the thirty-three subjects on all three trials was slightly lower than the grip strength mean of 77.0 pounds reported by Fisher et al. (30) for 96 female workers.

Examination of Figure XIV shows that, during the control period, the distribution of individual changes was relatively homogeneous. Fourteen of the thirty-three subjects increased their scores, 14 subjects decreased their scores and 5 subjects maintained the same score. Following the experimental period, 19 subjects increased their grip strength scores from one to fourteen pounds, while 8 subjects decreased and six maintained the same score.

Statistically significant increases in muscular endurance following isometric training have been reported recently (31, 32, 33, 34, 35, 36, 37). In the present study, muscular endurance of the abdominal muscles was measured by the total number of sit-ups that could be performed in two minutes. Following the control period, the mean number of sit-ups performed had decreased 1.14, but following the experimental period, there was a mean

increase of 3.3 sit-ups. The significant F ratio for trial differences (4.33) and Duncan's New Multiple Range Test showed that the mean increase of 3.3 sit-ups following the isometric training period was statistically significant at the .01 level of confidence. From Figure XII, it may be seen that, following isometric training, 24 of the thirty-three subjects increased in their ability to perform repeated sit-ups,while only six subjects decreased (following the control period, seventeen subjects had decreased and only twelve had increased their scores).

The F ratio for subject differences, obtained from the data for all eleven variables, was statistically significant at the .01 level of confidence indicating that, in all cases, some subjects were consistently better or worse than others. This bears out the observation put forth by Mathews and Kruse (11) that strength gain and training effects are dependent upon the individual rather than upon the exercise performed or the frequency of exercise.

Most studies which have shown statistically significant increases in strength following isometric training have used young men as subjects. Hettinger (38) had previously pointed out that women are less trainable than men. It was also noted, in the present study, that some young women will not put forth a maximum effort during testing if there is a possibility that muscle stiffness or soreness will result, while other subjects will exert a maximal effort regardless of any possible consequences. It is also possible that many young women will not be sufficiently motivated to put forth a maximum effort during isometric training or testing. Rasch and Morehouse (17) have noted that subjects express a dislike for isometric effort and Darcus and Salter (39) have observed that subjects become easily bored with isometric work. Ikai and Steinhaus (40) have noted that maximum isometric contractions do not give a true estimate of maximum physiological strength and believe that the expression of human strength is generally limited by

psychologically induced inhibitions.

As a result of these statements and personal observation, the writer feels that the scores obtained by the subjects in this study on strength and endurance measurements may not be indicative of actual ability. It is, therefore, recommended that similar studies be undertaken using female subjects of different ages and socio-economic statuses. It is felt, for example, the girls of junior high school age and older girls, who are more competitive and more highly trained than the subjects in this experiment, will be less hesitant to exert a maximal effort and will be more highly motivated. As a result, higher reliability coefficients for the measurements of strength and endurance may be obtained, as well as more marked increases in the strength and endurance scores.

Hettinger (38) also observed that lowest trainability occurred during the winter months of January, February and March. The present study took place over a twelve week period from December 11, 1962 to March 5, 1963, and trainability may thus have been influenced.

If further similar studies are undertaken using students as subjects, it is recommended that the experiment begin at the commencement of the fall term before the subjects have participated in any physical education activities. Such a schedule would attempt to eliminate the training effects of activities such as creative dance, on muscular strength or endurance of the quadriceps or other muscles. This schedule would usually avoid running the experiment into the winter months, at which time Hettinger states that trainability has been observed to be less.

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CHAPTER V

SUMMARY AND CONCLUSIONS

Thirty-three freshman women students at the University of Alberta in Edmonton, participated in a six week isometric training programme following a six week control period. The subjects acted as their own controls.

The two isometric exercises performed during the training period were:

1. Six daily six-second contractions of the muscles of the abdominal, gluteal and thigh region, with the subject standing erect. Each six-second contraction was alternated by two seconds of rest.

2. One daily six-second contraction of the muscles of the right hand and forearm, performed by clenching the fist with the hand supinated and the elbow flexed at a ninety degree angle and held against the side of the body.

Scores were obtained by the subjects on eleven variables - weight; waist, hip, right thigh and right forearm girths, as measured in inches with a Martin D.B.P. Circummeter steel anthropometric tape; abdominal, right rear thigh and right forearm skinfolds, as measured in millimetres with a Harpenden Skinfold Caliper; strength of the quadriceps muscles of the right leg, using Clarke's cable-tension strength test for the quadriceps; grip strength of the right hand, using a cable tensiometer with a hand grip apparatus; and muscular endurance of the abdominal muscles, as measured by the number of sit-ups performed in two minutes.

The Pearson Product-Moment formula was used to determine the test-retest reliability for the eleven variables measured. The scores obtained by the subjects on the retest (Trial 1), at the end of the six week control period (Trial 2) and following the six week experimental period (Trial 3), were subjected to analysis of variance. If a significant F ratio resulted

for trial differences, Duncan's New Multiple Range Test was employed to discover between which trials the significant mean change had occurred.

Following the statistical treatment, the following observations were made:

1. Throughout the experiment, no statistically significant changes occurred in weight, in girth of the waist or hips or right forearm, in rear thigh or right forearm skinfold, or in the strength of the quadriceps muscles of the right leg.

2. Following the control period, right thigh girth showed a mean increase of 0.363 inches, a change that was statistically significant at the .01 level of confidence.

3. Throughout the entire experiment from Trial 1 to Trial 3, abdominal skinfold showed a mean increase of 0.99 millimetres, a change which was statistically significant at the .05 level of confidence.

4. Following the six weeks of isometric training, the grip strength of the right hand showed a mean increase of 1.89 pounds, which was statistically significant at the .05 level of confidence. Nineteen of the thirty-three subjects improved in grip strength.

5. Following the six weeks of isometric training, there was a mean increase in the number of sit-ups performed in two minutes of 3.3. This change was statistically significant at the .01 level of confidence. Twenty-four of the thirty-three subjects improved in their ability to perform sit-ups.

6. For all eleven variables, the F ratios for subject differences were statistically significant at the .01 level of confidence, indicating that, throughout the twelve weeks of the experiment, some subjects changed consistently more than others.

Within the limitations of the present study, the following conclusions were made:

1. During a period of relative inactivity, young women tend to deposit fat in the thigh and waist areas. This is evidenced by the statistically significant increases in thigh girth during the control period and in abdominal skinfold over the entire twelve weeks. Such deposition of fat may occur without an increase in weight, as no statistically significant change in weight took place.

2. Following six weeks of isometric training by performing one daily six-second maximal contraction of the hand and wrist muscles, young college women showed an increase in grip <u>strength</u>, which was statistically significant at the .05 level of confidence.

3. Following six weeks of isometric training by performing six daily six-second maximal contractions of the abdominal, gluteal and thigh muscles in a standing position, young college women showed an increase in the <u>muscular endurance</u> of the abdominal muscles that was statistically significant at the .01 level of confidence.

Recommendations for Further Study

It is recommended that similar research be carried out using younger girls, or older, more competitive girls, as subjects. It is felt that such subjects would be more highly motivated and more likely to put forth a maximal effort during training and testing.

It is further recommended that studies, using students as subjects, take place at the beginning of the fall term before the subjects have participated in physical education activities.

Because of the principle of specificity, it is recommended that young women be trained, using isometric contractions in the same position in which they will be tested.

It is felt that more meaningful results will be obtained if thigh

girth and skinfold measurements are taken at the same site.

It is recommended that more attention be given to individual differences, as it has been observed that some subjects are more trainable than others.

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APPENDIX A

STATISTICAL TREATMENT

STATISTICAL TREATMENT

Raw scores were obtained for the thirty-three subjects on eleven variables:

1. Weight
2. Waist Girth
3. Hip Girth
4. Right Thigh Girth
5. Right Forearm Girth
6. Abdominal Skinfold
7. Right Rear Thigh Skinfold
8. Right Forearm Skinfold
9. Strength of Right Quadriceps Extension
10. Right Grip Strength
11. Abdominal Muscular Endurance (number of sit-ups)

Four trials were given on each variable - initial test; retest after four days; final control test following the six week control period; and, final experimental test after the next six weeks.

A. Reliability of Measurements. In order to determine the reliability of the measurements for each of the eleven variables, the test-retest reliability was found by the Pearson Product-Moment method (1:143):

$$r = \frac{N \Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{\left[N \Sigma X^2 - (\Sigma X)^2\right]\left[N \Sigma Y^2 - (\Sigma Y)^2\right]}}$$

where X = test score

Y = retest score

The same procedure was followed for each of the eleven variables.

Following the calculation of the reliability coefficients, the initial test scores were mo longer used. The retest scores became known

as the Trial 1 scores; the final control period scores were referred to as the Trial 2 scores; and, the final experimental period scores were known as the Trial 3 scores.

B. <u>Analysis of Variance.</u> In order to determine the statistical significance of any changes that had occurred during the experiment, the raw data for each of the eleven variables were subjected to analysis of variance, using the formula for single groups (1:291):

<u>Step 1</u>. The sum of scores for each trial was calculated:

ΣX_1 ; ΣX_2 ; ΣX_3

<u>Step 2.</u> The Grand Sum of all the scores was calculated:

$\Sigma X = \Sigma X_1 + \Sigma X_2 + \Sigma X_3$

<u>Step 3.</u> The Mean Score for each trial was calculated:

$$\bar{X}_1 = \frac{\Sigma X_1}{N}$$

$$\bar{X}_2 = \frac{\Sigma X_2}{N}$$

$$\bar{X}_3 = \frac{\Sigma X_3}{N}$$

<u>Step 4</u>. The correction term was calculated by squaring the grand sum of all scores for the three trials and by dividing by the total number of scores for the three trials, in this case - 99.

$$C = \frac{(\Sigma X)^2}{N}$$

<u>Step 5.</u> The total sum of squares around the general mean was found by squaring each score, summing the squares, and subtracting the correction term.

$$\text{Total SS} = (X_{01}^2 + X_{02}^2 + \ldots + X_{98}^2 + X_{99}^2) - C$$

<u>Step 6.</u> The sum of squares between the means of the trials was calculated by squaring the sum of the scores for each trial, adding the three squares together, dividing by the number of scores in each trial (33) and subtracting the

correction factor.

$$SS_{trials} = \frac{(\Sigma X_1)^2 + (\Sigma X_2)^2 + (\Sigma X_3)^2}{n} - C$$

Step 7. The sum of squares among the means of the subjects was found by adding the three scores for each subject, squaring each total, and summing the squares. The sum of squares was divided by (k = trials = 3) and the correction factor was subtracted.

$$SS_{subjects} = \frac{\overset{\Sigma 1-33}{(X_1 + X_2 + X_3)^2}}{k (or\ 3)} - C$$

Step 8. The residual variation or interaction is whatever is left when the systematic effects of trial differences and subject differences have been removed from the total sum of squares. Interaction measures the tendency for subject performance to vary along with trials; it measures the factors attributable neither to subjects nor trials acting alone, but rather to both acting together. Interaction was obtained by subtracting the trials SS plus subjects SS from the total SS.

$$\text{Interaction SS} = \text{Total SS} - (SS_{subjects} + SS_{trials})$$

Step 9. The sums of squares become variances when divided by the appropriate degress of freedom. If N = total number of scores, r = rows and K = columns:

df for total SS = (N-1) = (99-1) = 98

df for column SS (trials) = (k-1) = (3-1) = 2

df for row SS (subjects) = (r-1) = (33-1) = 32

df for interaction SS = (k-1) (r-1) = (2) (32) = 64

Step 10. Each sum of squares became a variance when divided by the degrees of freedom allotted it (Step 9). The mean square or variance for the sum of squares between trials 1, 2 and 3 was found by:

$$\text{Variance (between trials)} = \frac{\text{Between Trials SS}}{(k-1) \text{ or } 2}$$

The mean square or variance for the sum of squares among subjects was found by:

$$\text{Variance (among subjects)} = \frac{\text{Among Subjects SS}}{(r-1) \text{ or } 32}$$

The mean square or variance for the interaction sum of squares was found by:

$$\text{Variance (interaction)} = \frac{\text{Interaction SS}}{(k-1)(r-1) \text{ or } 96}$$

Step 11. Two F ratios were calculated, one for trial differences and one for subject differences. In both cases, the interaction variance is placed in the denominator of the variance ratio, since it is the best estimate of experimental error or residual variance after the systematic influences of trials and subjects have been removed.

$$F_{\text{trials}} = \frac{\text{Variance (between trials)}}{\text{Variance (interaction)}}$$

$$F_{\text{subjects}} = \frac{\text{Variance (among subjects)}}{\text{Variance (interaction)}}$$

Step 12. In the present problem, the null hypothesis asserted that the three sets of scores were equal. The null hypothesis ($H: \bar{X}_1 = \bar{X}_2 = \bar{X}_3 = \bar{X}$) was tested by applying an F test to the F ratios found for each of the eleven variables.

If $F \leq$ the value of the table, accept H

If $F >$ the value of the table, reject H

In Table F, it was found that when $df_1 = 2$ and $df_2 = 64$, F at $.01 = 4.98$, and F at $.05 = 3.15$. The F ratio for trials was tested against these values. It was found that when $df_1 = 32$ and $df_2 = 64$, F at $.01 = 1.60$ and F at $.05 = 1.39$. The F ratio for subjects was tested against these values.

If it is found that the F ratio is not significant (less than or equal to the critical value in the table), the null hypothesis, that all the means are equal, was not rejected. If the F is not significant, there was no reason for further testing as none of the mean differences would be statistically significant.

If, however, the F ratio had been found to be significant (greater than the critical value in the table), the null hypothesis would have been rejected. A significant F does not tell us which means differ significantly, but merely that one is reliably different from the others. Then, the separate differences were tested by applying Duncan's New Multiple Range Test.(2:136-139), for use when the same number of observations is present for each mean.

C. Duncan's New Multiple Range Test. The first step in applying the multiple range test is to arrange the means in order of magnitude.

Then the standard error of a single mean may be found by:

$$S_{\bar{X}} = \frac{S}{n}$$

where s = the square root of the interaction (error) mean square of the analysis of variance, and

n = the number of observations on which the mean is based, in this case, n is equal to 33.

Because the standard error of a single mean is based upon the interaction mean square (with 64 degrees of freedom and three means involved) the table of significant studentized ranges for Duncan's New Multiple Range Test was entered with $k = 3$ and $df = 64$. It was found that, for $\alpha .05$, r_2 was equal to 2.829 and r_3 was equal to 2.976. For $\alpha .01$, r_2 was equal to 3.762 and r_3 was equal to 3.922.

Each significant studentized range was the multiplied by the standard error of the mean ($S_{\bar{X}}$). The resulting values are called the shortest significant ranges.

The differences between the pairs of means were tested, beginning with the largest minus and the smallest mean. Each mean difference is significant if it is found to exceed the corresponding shortest significant range. A mean difference covering two means must exceed r_2 at the .05 or .01 levels of confidence and a mean difference covering three means must exceed r_3 at the .05 or .01 levels of confidence.

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APPENDIX B

INDIVIDUAL SCORE SHEET

NAME: ______________________________

ADDRESS: ______________________________

PHONE NO.: ________________

GE: __________ years, ________ months

	TEST	RETEST	FINAL C.	FINAL EXP.
. Weight				lbs.
. Girth - waist				in.
hips				in.
r. thigh				in.
r. forearm				in.
Subc. fat - abdomen				mm.
r. thigh post.				mm.
r. forearm				mm.
Strength of quadriceps				lbs.
Right grip strength				lbs.
Number sit-ups				

letic activities engaged in on a regular club, team, or recreational basis:

____

____

APPENDIX C

RAW SCORES

RAW SCORES

1. Weight (pounds)

Subject	Test	Retest	Final Control	Final Experimental
01	123.25	123.00	124.00	124.00
02	125.00	123.75	119.75	121.00
03	119.25	117.75	112.75	108.50
04	130.50	130.50	128.75	129.00
05	114.75	117.00	113.00	108.25
06	118.50	119.50	118.00	119.75
07	149.00	153.00	151.50	152.75
08	105.75	105.75	106.25	104.00
09	126.25	124.50	124.50	125.75
10	104.50	103.25	103.25	104.00
11	108.25	108.75	109.50	108.50
12	122.00	123.25	124.50	125.00
13	121.50	122.50	121.75	122.00
14	151.75	149.50	150.75	149.75
15	120.50	119.25	123.00	123.00
16	93.50	92.75	94.25	94.50
17	132.25	133.00	133.00	132.75
18	114.25	114.50	118.00	117.50
19	127.00	126.75	132.00	131.25
20	146.50	146.00	143.00	149.00
21	150.00	151.50	155.00	155.50
22	113.00	113.50	112.00	114.50
23	135.50	137.00	142.00	151.00
24	120.75	121.50	118.50	118.00
25	119.00	117.00	116.50	114.75
26	126.75	125.50	125.50	126.00
27	156.00	156.50	158.50	160.50
28	112.00	112.00	113.75	117.00
29	147.50	146.00	146.25	147.50
30	104.00	103.00	102.00	100.50
31	131.00	130.00	131.00	130.00
32	138.00	139.00	136.00	135.25
33	127.25	128.50	128.25	130.00

2. Waist Girth (inches)

Subject	Test	Retest	Final Control	Final Experimental
01	25.375	24.936	25.125	24.313
02	24.063	24.438	24.688	24.750
03	26.563	25.563	25.313	23.813
04	24.438	25.000	24.750	24.188
05	25.375	25.500	25.000	24.500
06	22.750	23.000	22.375	22.938
07	27.375	28.375	29.000	27.688
08	23.938	23.250	23.875	23.875
09	24.875	24.438	24.500	23.813
10	22.500	22.250	22.438	22.125
11	22.938	23.438	23.125	23.000
12	26.063	26.938	26.688	26.000
13	24.000	25.250	24.500	24.000
14	27.000	26.813	27.188	27.375
15	25.500	25.750	26.813	26.500
16	22.625	22.500	22.938	22.750
17	26.750	25.938	25.500	25.563
18	23.875	24.063	24.438	23.813
19	25.625	24.750	26.313	26.000
20	28.938	28.063	27.063	29.000
21	26.813	26.625	27.688	27.250
22	23.000	23.438	22.813	22.250
23	23.313	24.125	24.563	25.313
24	23.813	23.563	22.938	23.000
25	23.750	24.063	23.875	22.313
26	25.063	24.250	24.750	24.438
27	27.125	27.750	27.688	27.688
28	24.750	25.250	25.438	25.688
29	27.813	27.000	27.000	27.375
30	22.875	23.750	21.688	22.250
31	26.500	26.250	26.000	25.438
32	27.063	28.188	28.250	26.688
33	24.500	25.000	25.000	24.815

3. Hip Girth (inches)

Subject	Test	Retest	Final Control	Final Experimental
01	36.250	37.500	36.875	36.875
02	36.125	36.375	35.438	35.875
03	36.875	37.000	36.750	36.375
04	36.500	36.625	36.438	36.313
05	35.250	35.875	35.125	35.000
06	36.125	36.063	35.938	35.813
07	37.563	37.875	37.625	38.375
08	34.375	35.313	35.313	35.500
09	35.250	35.063	36.000	36.125
10	34.188	34.125	34.375	34.250
11	34.938	34.250	34.375	34.250
12	36.000	36.188	36.875	36.938
13	36.438	37.188	37.000	36.688
14	38.375	38.938	39.313	38.438
15	35.750	35.500	36.563	36.125
16	31.375	32.313	32.563	32.625
17	36.500	36.500	36.500	37.125
18	35.750	35.625	36.375	35.875
19	37.188	37.125	37.875	37.188
20	38.000	38.500	38.813	38.813
21	38.313	39.313	40.250	39.563
22	35.063	35.563	35.875	34.813
23	36.875	37.063	38.438	39.625
24	36.750	36.688	36.875	35.375
25	34.250	34.625	34.500	34.188
26	35.875	36.188	36.063	37.125
27	39.313	39.625	40.625	40.375
28	34.563	34.500	35.438	36.125
29	39.625	38.313	39.375	40.000
30	34.750	35.375	34.563	34.313
31	38.625	38.500	38.938	38.500
32	37.188	38.125	37.188	37.188
33	36.625	37.500	36.875	37.500

4. Right Thigh Girth (inches)

Subject	Test	Retest	Final Control	Final Experimental
01	21.313	20.938	21.875	21.375
02	20.250	20.188	19.813	20.125
03	21.188	21.125	21.250	20.438
04	20.313	20.250	19.875	19.813
05	20.125	20.000	19.625	19.500
06	20.625	20.563	20.625	20.875
07	21.938	22.063	22.438	22.125
08	20.188	20.125	20.688	20.188
09	21.000	20.813	21.500	21.000
10	18.625	18.625	19.188	18.813
11	19.313	19.188	19.375	19.188
12	20.625	20.625	20.938	21.000
13	20.688	20.375	21.625	21.375
14	23.000	23.188	23.813	23.500
15	20.625	20.375	21.250	21.000
16	17.250	17.750	17.938	17.625
17	22.000	22.063	22.000	21.875
18	20.875	20.813	22.000	21.813
19	20.375	20.500	21.875	21.125
20	22.438	22.563	22.438	22.875
21	22.625	22.938	24.063	23.750
22	20.188	20.500	20.375	20.438
23	21.500	21.813	22.438	23.250
24	20.750	20.250	20.375	19.438
25	20.438	20.375	20.188	20.375
26	22.250	21.938	22.563	21.813
27	23.813	23.500	24.188	24.125
28	20.125	20.500	21.000	21.375
29	22.750	22.813	23.313	22.938
30	19.125	19.188	18.938	17.875
31	21.313	22.375	22.500	22.250
32	22.188	22.000	22.125	21.938
33	20.750	19.938	20.063	21.188

5. Right Forearm Girth (inches)

Subject	Test	Retest	Final Control	Final Experimental
01	8.750	8.563	8.750	8.562
02	9.188	9.125	9.125	9.000
03	8.875	8.750	8.625	8.313
04	8.750	9.000	9.063	9.063
05	8.500	8.500	8.875	8.750
06	8.813	8.750	8.125	8.875
07	9.750	9.500	9.750	9.688
08	8.313	8.375	8.438	8.375
09	9.188	9.125	9.125	9.000
10	7.750	8.063	8.063	8.000
11	8.188	8.188	8.250	8.250
12	8.750	8.875	8.938	8.813
13	9.063	9.188	9.063	9.125
14	10.000	10.000	10.000	9.938
15	8.625	8.750	8.813	8.625
16	7.625	7.625	7.688	7.688
17	9.313	9.250	9.438	9.500
18	8.375	8.500	8.938	8.813
19	8.625	8.750	8.938	8.750
20	9.813	9.750	9.813	10.063
21	9.625	9.750	10.063	10.125
22	8.625	8.875	8.750	8.813
23	9.625	9.625	9.875	10.000
24	8.438	8.500	8.500	8.438
25	9.000	9.000	9.000	9.000
26	9.688	9.625	9.688	9.813
27	9.250	9.250	9.375	9.125
28	8.875	8.750	8.688	8.813
29	9.813	9.750	10.000	9.938
30	8.125	8.063	8.125	7.875
31	9.375	9.250	9.313	9.313
32	8.875	8.875	8.938	8.938
33	9.063	9.125	9.188	9.250

6. Abdominal Skinfold (millimetres)

Subject	Test	Retest	Final Control	Final Experimental
01	11.2	12.3	13.2	18.1
02	8.0	9.2	8.4	9.2
03	12.1	10.2	11.4	7.4
04	15.2	16.0	15.1	16.2
05	11.0	10.0	10.4	10.1
06	7.4	7.2	7.1	7.1
07	7.2	7.0	11.2	7.3
08	26.4	24.1	27.1	22.3
09	15.3	14.4	14.1	16.3
10	6.3	6.4	7.0	7.1
11	8.4	8.4	10.2	11.0
12	8.1	9.0	10.4	11.2
13	10.3	9.1	12.2	12.1
14	11.4	9.3	12.0	10.2
15	7.4	7.1	8.1	9.4
16	9.1	9.3	13.1	8.2
17	9.1	9.4	10.1	11.0
18	10.0	12.0	10.3	12.0
19	6.1	8.4	7.1	10.2
20	10.3	11.5	10.3	11.1
21	9.4	9.4	9.4	12.1
22	7.0	11.0	9.1	12.1
23	6.1	6.3	7.4	6.4
24	6.4	7.2	7.2	6.3
25	8.3	8.1	8.1	8.3
26	8.0	7.1	7.4	8.4
27	11.0	10.1	14.1	18.1
28	6.4	7.1	7.3	7.3
29	9.3	11.2	10.4	10.3
30	25.0	25.2	29.3	26.3
31	19.1	20.1	19.4	23.2
32	7.3	7.2	7.2	7.4
33	6.2	8.3	7.3	7.4

7. Rear Thigh Skinfold (millimetres)

Subject	Test	Retest	Final Control	Final Experimental
01	31.3	30.3	32.2	33.2
02	21.4	27.2	31.1	28.4
03	32.4	35.0	31.0	31.1
04	25.3	27.0	26.1	30.1
05	27.0	28.3	24.1	27.1
06	29.2	24.3	28.2	31.4
07	35.3	32.3	39.4	34.4
08	37.1	35.4	38.1	38.1
09	31.4	28.2	33.1	31.4
10	26.1	22.1	24.1	19.2
11	29.2	26.1	24.1	24.1
12	20.2	25.2	22.4	30.3
13	28.3	28.4	28.0	27.1
14	25.2	30.0	31.4	30.2
15	26.1	24.1	28.2	23.3
16	23.2	25.1	23.1	28.2
17	29.2	27.2	28.1	23.4
18	25.2	25.1	25.2	26.3
19	28.4	23.1	25.3	28.2
20	36.3	33.2	32.1	31.1
21	38.3	33.2	33.1	34.0
22	19.4	23.4	22.1	24.2
23	31.2	26.0	25.3	32.1
24	25.2	25.2	25.2	25.0
25	23.7	20.1	29.1	29.4
26	39.9	37.4	35.3	36.1
27	33.1	34.2	34.1	32.1
28	28.2	28.0	28.4	30.2
29	29.4	29.1	33.3	32.4
30	29.1	28.1	32.0	29.1
31	30.0	29.2	25.1	29.1
32	31.2	38.1	32.2	35.3
33	22.3	24.3	24.1	23.1

8. Forearm Skinfold (millimetres)

Subject	Test	Retest	Final Control	Final Experimental
01	9.2	9.1	8.2	8.1
02	7.0	5.4	7.0	6.0
03	9.2	11.0	9.3	8.4
04	9.0	9.0	8.3	8.2
05	4.4	4.2	5.3	4.0
06	7.1	8.2	7.2	7.4
07	8.1	8.2	9.4	8.0
08	9.0	9.1	9.2	9.1
09	6.1	6.1	8.3	6.1
10	6.0	6.1	6.1	5.3
11	6.4	7.1	6.4	7.2
12	6.0	5.4	6.4	7.1
13	8.1	8.0	8.2	8.2
14	11.2	13.0	11.4	11.0
15	6.4	7.1	7.4	6.4
16	5.0	5.4	7.0	6.0
17	8.4	10.4	9.3	8.3
18	10.1	9.1	12.1	11.1
19	4.4	5.0	5.2	5.3
20	8.3	8.4	9.1	9.3
21	10.3	10.4	10.2	11.1
22	4.1	4.0	3.4	4.2
23	8.1	8.3	9.2	11.0
24	4.3	5.3	5.3	4.4
25	7.2	7.1	8.3	6.4
26	9.4	8.0	9.3	8.3
27	11.4	11.0	10.3	11.1
28	6.1	6.2	6.2	6.2
29	7.1	7.0	6.3	6.1
30	4.4	5.1	5.1	4.3
31	7.3	7.4	8.4	7.4
32	7.3	8.1	7.4	8.3
33	8.2	8.2	7.2	8.0

9. Quadriceps Strength (pounds)

Subject	Test	Retest	Final Control	Final Experimental
01	147	177	170	163
02	134	177	174	139
03	134	124	153	112
04	127	147	160	144
05	160	167	155	136
06	167	209	202	163
07	184	191	147	144
08	108	124	127	116
09	124	094	196	190
10	150	140	124	150
11	158	155	187	160
12	184	171	220	173
13	107	105	114	124
14	180	220	220	188
15	167	143	160	138
16	95	124	116	98
17	184	202	196	204
18	107	90	147	130
19	147	103	174	160
20	138	150	174	196
21	144	180	171	220
22	160	164	158	136
23	167	160	118	95
24	83	100	87	110
25	121	138	150	147
26	162	206	210	244
27	196	206	209	196
28	140	127	167	140
29	186	210	220	214
30	150	170	184	136
31	174	180	206	216
32	142	147	139	147
33	152	144	178	127

10. Grip Strength (pounds)

Subject	Test	Retest	Final Control	Final Experimental
01	70	81	81	81
02	75	83	90	99
03	47	62	62	63
04	56	54	49	47
05	56	70	67	64
06	64	67	65	63
07	69	62	79	70
08	50	52	52	56
09	72	78	80	73
10	63	77	80	82
11	58	66	65	70
12	75	78	80	70
13	56	64	60	70
14	70	66	68	70
15	63	68	65	70
16	59	68	70	70
17	70	72	70	67
18	57	57	62	64
19	59	60	64	65
20	63	63	59	66
21	67	82	78	92
22	70	64	54	64
23	80	82	82	87
24	47	58	54	63
25	54	67	66	66
26	66	73	77	82
27	66	75	77	77
28	67	64	73	75
29	70	77	79	79
30	46	58	54	62
31	61	73	73	73
32	58	79	72	77
33	60	64	73	65

11. Number of Sit-Ups

Subject	Test	Retest	Final Control	Final Experimental
01	41	46	32	35
02	20	10	13	22
03	34	38	32	34
04	20	14	15	17
05	26	30	28	36
06	22	31	22	27
07	30	30	30	22
08	35	19	28	30
09	41	30	26	22
10	28	29	26	30
11	20	10	15	15
12	40	33	33	31
13	18	19	20	22
14	19	28	19	30
15	33	37	36	33
16	24	23	12	28
17	24	26	26	18
18	26	39	34	35
19	21	25	23	25
20	20	25	20	26
21	28	32	30	33
22	26	20	20	30
23	28	31	30	30
24	37	39	40	53
25	22	29	18	29
26	39	38	40	40
27	7	7	9	7
28	51	32	49	61
29	22	33	29	32
30	19	19	21	22
31	14	23	20	24
32	20	12	19	22
33	29	26	30	33